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OF

PHILADELPHIA

VOLUME XVI

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1899

THE ENGINEERS' CLUB OF PHILADELPHIA

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The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

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Vol. XVI. JANUARY, 1899. No. 1.

PENNSYLVANIA AVENUE SUBWAY AND TUNNEL.

GEORGE S. WEBSTER.

Read October 15, 1898.

The work of abolishing seventeen dangerous grade-crossings of the Philadelphia & Reading Railway, on the line of Pennsylvania Avenue, in the heart of the city of Philadelphia, involving an expenditure of approximately six millions of dollars, is one of such magnitude and covers so many engineering difficulties that a description of the work while in progress may prove interesting. In speaking of this important work it may be well to mention a few reasons which led to the construction of the subway and tunnel.

Councils, by ordinance of December 26, 1890, authorized the construction of the Philadelphia & Reading Terminal Railroad to Twelfth and Market Streets, conditioned, among other things, upon the Railroad Company, at the points where its allied Companies' tracks crossed Broad Street at Pennsylvania Avenue and near Lehigh Avenue, raising the grade of Broad Street about twenty-one feet, so as to carry it by bridges over the tracks of the railroads. After the construction of the bridge and its approaches near Lehigh Avenue, in the northern part of the city, it was clearly demonstrated that a similar raising of the grade (or humping) of Broad Street at Pennsylvania Avenue, almost in the heart of our city, would not only seriously damage valu-

able property, but would practically ruin the city's finest avenue,—the one always used for military and civic displays,—and would still leave sixteen dangerous grade-crossings to the westward unprovided for. So other means of accomplishing the result were sought.

The question of elevating the railroad tracks from Thirteenth Street to Thirtieth Street was considered; but as such construction would result in all of the intersecting streets being crossed overhead by steel bridges (probably of the plate-girder type), over which fast-moving trains would be constantly passing,—and particularly as the highways to be built over included, in addition to Broad Street, Twenty-second Street, Spring Garden Street, Green Street, and Fairmount Avenue (the principal entrances to Fairmount Park),—it was seriously objected to by the citizens of the southern and central parts of the city. The bridge over Broad Street was particularly protested against, owing to the fact that not only the tracks leading to the Terminal, but also a connection to the Willow Street branch and the sidings to the freight house located east of Broad Street, would have to be provided for,—resulting in a bridge 265 feet long,—and which, in addition to the inconvenience to the general public, would almost completely cut off the view along the city's great boulevard.

A careful study of the problem by the engineers of the city of Philadelphia, of the Philadelphia & Reading Railway Company, and the late Mr. John A. Wilson, Consulting Engineer, was made, and resulted in the preparation of plans and estimates for depressing the tracks and carrying them, in subway and tunnel, under all streets—thus permanently abolishing the crossings at grade, providing for railroad business, and the maintenance of adequate track connections with industrial establishments along the line. The advantages of the subway are that it produces no disfigurement of the streets crossing it; the grades being so arranged that the superstructures of the bridges are beneath the level of the streets, thus presenting an unbroken contour of the same. By means of the tunnel from Twenty-second Street west, all tracks will be removed from sight, and what is now a half-blighted section of the city will be reclaimed, resulting in improved and increased value to private property, obtaining for the city a splendid additional driveway, and an appropriate entrance to Fairmount Park, freed from all objectionable features, and will result in a partial financial return to the city in increased taxes.

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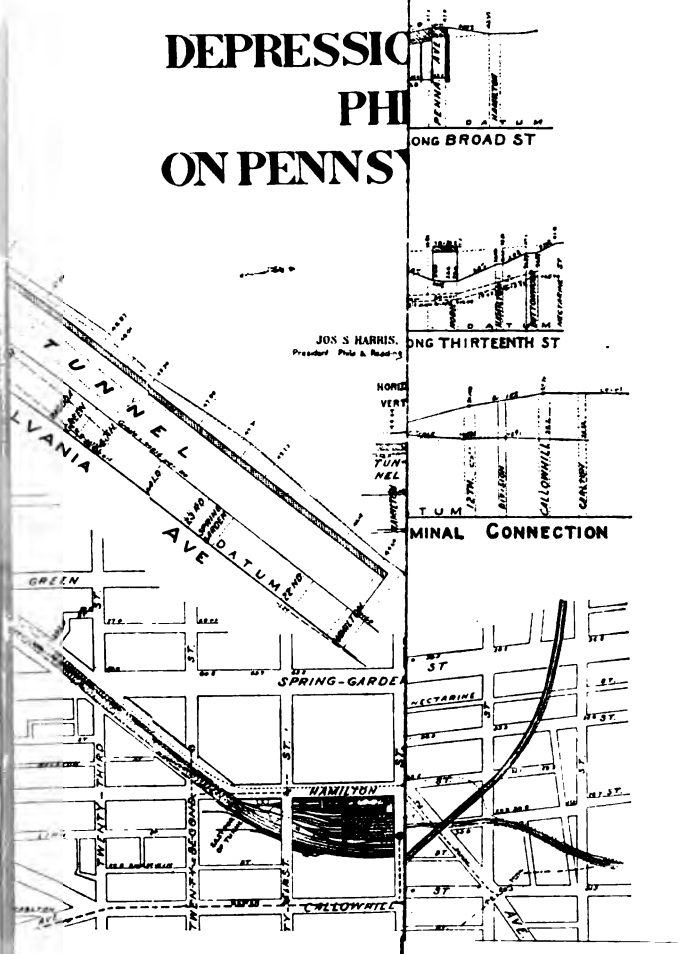

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Requirements of Ordinance.

On March 17, 1894, an ordinance was enacted to authorize the work necessary to abolish all grade-crossings on the line of Pennsylvania Avenue and Noble Street, between the east side of Thirteenth Street and Poplar Street.

The accomplishment of the work authorized by this ordinance involves the depression of the tracks and yards of the Philadelphia & Reading Railroad Company between Broad Street and Thirtieth Street, including the alterations of the lines and grades of the tracks and yards between the north side of Noble Street and Callowhill Street, and between Eleventh Street and Broad Street; the alteration of the lines and grades of the tracks of the Philadelphia & Reading Terminal Railroad east of Broad Street and between Noble Street and Carlton Street. Accompanying this depression and alteration of tracks and yards is the alteration, construction, and reconstruction of all the yard tracks, freight, engine, depot, and signal buildings and other structures of the Philadelphia & Reading Railroad Company, so as to provide as much accommodation and as full and convenient a method for operation and conducting business as now exists. Adequate track connections with the various industrial establishments along the line of the Philadelphia & Reading Railroad are also provided; provision was made for the construction of temporary tracks and bridges for maintaining travel on the railroad and upon all of the intersecting streets.

Bridges with adequate approaches were made necessary to carry Broad, Fifteenth, Sixteenth, Seventeenth, Eighteenth, Nineteenth, Twentieth, and Twenty-first Streets over the subway. Also bridges for Twelfth and Thirteenth Streets are to be built to carry the railroad over them.

Provision was made for carrying the tracks of the Philadelphia & Reading Railroad, by open subway, with the necessary retaining walls, and the underpinning of all structures along the line from near Broad Street to Hamilton Street, and by tunnel from Hamilton Street to near Taney Street; thence by open subway to a point near Thirtieth Street.

The elevated structure, which extends from Callowhill Street, between Eleventh and Twelfth Streets, to Thirteenth and Noble

Streets, is 959 feet in length. The subway, from Thirteenth Street to a point east of Twenty-second Street, is 4180 feet in length. The tunnel has a length of 2711 feet from east of Twenty-second Street to a point west of Twenty-sixth Street; and the open subway to the westward is 2150 feet long, terminating at Thirtieth Street. The total length of the work is therefore about 10,000 feet, or nearly two miles.

The entire reconstruction of the sewerage system between Twelfth and Thirtieth Streets was necessary, and considerable alteration in the gas- and water-mains and electric conduits was also required.

The Director of the Department of Public Works is, under ordinance, directed to confer during the progress of the work with an engineer to be appointed by the Philadelphia & Reading Railroad Company, in regard to carrying out the specifications and securing the due performance of the contract.

On March 30, 1894, Mr. John A. Wilson was appointed Consulting Engineer, to represent the Philadelphia & Reading Railroad Company. Upon the death of Mr. John A. Wilson, on January 19, 1896, Mr. Joseph M. Wilson was appointed in his stead on January 23d.

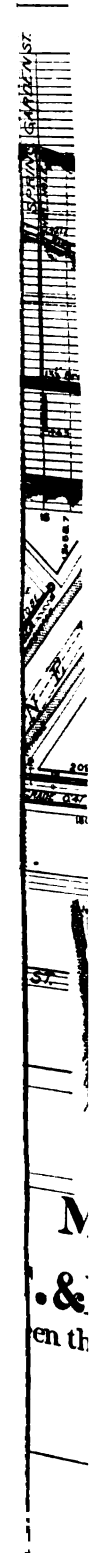
The estimated cost of this work, including damages to property, is six million ($6,000,000) dollars, of which the Philadelphia & Reading Railroad Company is to pay one-half. By ordinance of March 15, 1894, a loan of six million ($6,000,000) dollars was authorized, and preparations for beginning the work were at once made.

Description of Work.

Three independent systems of main sewers, having a total length of about 3½ miles, were necessary to drain the territory, with its new conditions. Entirely new sewers were constructed, as no existing system was deep enough for use.

On account of the new sewers being in the heart of a great city almost entirely built up, and on account of their duty being from twenty-five to forty-five feet beneath the surface of the streets, it was specified that they should, wherever practicable, be constructed in tunnel, so that the interference with street traffic would be reduced to a minimum.

Fifty-five shafts were, therefore, sunk at various points and tun-



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CONSTRUCTION OF SEWER IN TUNNEL.

CONSTRUCTION OF SEWER IN TUNNEL.

nel headings driven from them. Hoisting engines with derricks, generally driven by compressed air, so as to cause as little inconvenience to the residents as possible, were placed over each shaft to lift the waste material. The tunnel headings when in rock were almost invariably worked with Ingersoll-Sergeant or Rand drills, driven by compressed air. In soft and rotten rock hand-drills were most frequently used.

Water- and gas-mains, electric conduits, and old sewers, many of which did not appear on the records of the different bureaus, offered serious menace, danger, and several times damage, to the construction of the new sewers. By the caving in of the inverts of old sewers directly above those being built considerable delay was incurred.

The work of constructing the outlets into the Schuylkill River at Powelton Avenue and Wood Street was exceedingly tedious, owing to the fact that the sewer had to be built on piles and platform through an old wharf, with the top of the platform below mean low water, requiring the use of a diver, and making it necessary to work for a time at low tide only. On Pennsylvania Avenue between Green Street and Fairmount Avenue the tunnel excavation was carried on beneath dwellings, a large number of which were occupied. All open spaces between the brickwork of the sewer and sides of the tunnel were filled with rubble masonry.

The three systems into which the sewers for carrying on this work were divided are as follows:

1. Twenty-fourth Street and Pennsylvania Avenue system.

This system provides for the drainage west of Twenty-fourth Street on the north side of Pennsylvania Avenue, intercepting all the cross streets between Twenty-fourth and Thirtieth Streets, carrying the same under the subway down Twenty-fourth Street to Powelton Avenue, and on the line of Powelton Avenue to the Schuylkill River.

2. Callowhill Street system.

This system provides for the drainage of the subway and tunnel from Thirteenth to Twenty-third Streets, by means of a main sewer on Callowhill Street, with appurtenant sewers on the cross streets leading under the subway, and receiving through well-holes the water from the old sewers to the north. From Twenty-third Street the

CONSTRUCTION OF SEWER THROUGH ROCK.

main sewer follows Powelton Avenue to Twenty-fourth Street, passes along Twenty-fourth Street to Wood Street, and thence into the Schuylkill River.

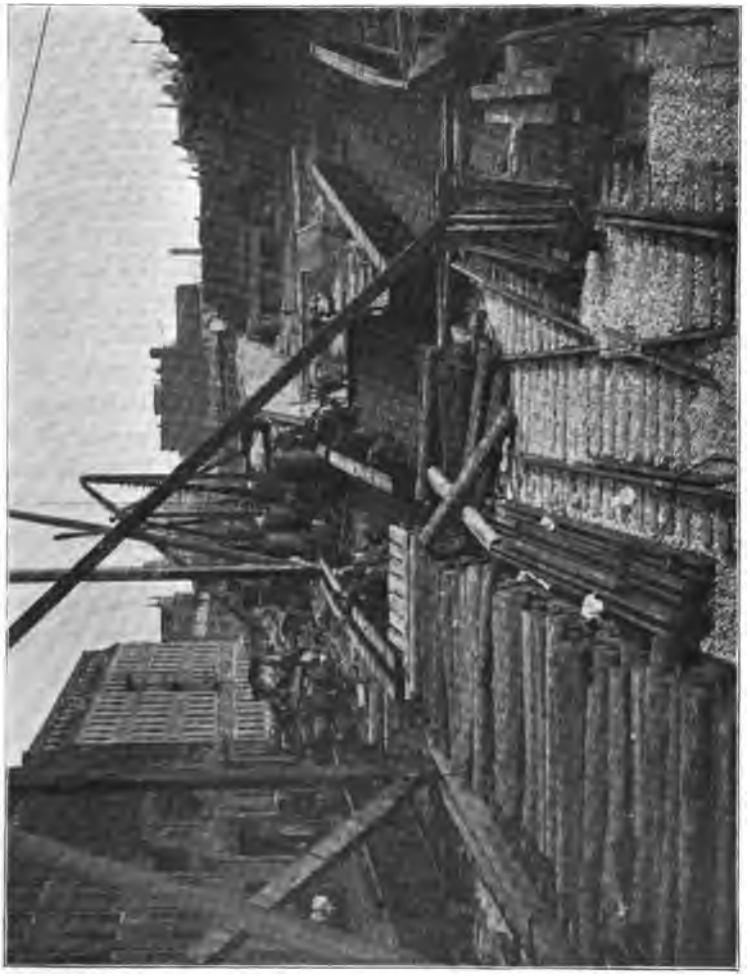
3. Twelfth Street system.

This sewer is designed to intercept the old Thirteenth Street main sewer, carrying it down Buttonwood Street to Twelfth Street, thence along Twelfth Street to Carlton Street, where it discharges into an old main sewer on the Delaware River watershed.

Driving tunnels and constructing sewers beneath the streets in the heart of a great city; maintaining the flow in existing sewers and other municipal structures; requiring blasting in the closest proximity to industrial establishments containing delicate machinery; meeting treacherous quicksands through which the sewers must be constructed; fighting the tides where the construction extended through old wharves with the foundation below the level of low tide;—all these circumstances required the greatest diligence on the part of the engineers and contractors in order to accomplish the desired end. In spite of these and many other difficulties these sewers have been finished in a satisfactory manner.

Upon the completion of the subway and tunnel the tracks of the Philadelphia & Reading Railway Company from Twelfth Street to Broad Street will descend by a grade of 2½ feet per 100 to the depressed yard. The tracks will cross Thirteenth Street at about the present grade, necessitating the lowering of that street so as to pass under the railroad. Between Thirteenth Street and a point near Sixteenth Street the entire space between the north side of Callowhill Street and the north side of Pennsylvania Avenue has been excavated, forming a depressed yard. Broad Street and Fifteenth Street are carried over this yard on bridges. From Sixteenth Street to Twenty-second Street the tracks run on a comparatively flat grade through a subway generally about eighty feet wide and having twenty feet clearance between the top of the rail and the bottom of the girders at the street crossings. The streets will be carried over the subway on plate girder-decked bridges. The side-walls are generally vertical, of rubble masonry. The present triangular yard between Twentieth Street, Hamilton Street, and Pennsylvania Avenue is to be excavated to subgrade, and Twentieth Street carried across on a bridge. This

yard will contain the new engine house, freight house, and repair shop. From a point east of Twenty-second Street a tunnel will extend to a point near the entrance of the B. & O. R. R. tunnel west



BRIDGE OVER THIRTEENTH STREET.

of Twenty-sixth Street. From this latter point to Thirtieth Street the tracks will ascend with a 1.3 per cent. grade to the original grade at Thirtieth Street.

In order to carry on the work along the line of Pennsylvania Avenue and maintain the railroad travel and keep up connections with industrial establishments, it was necessary to lay a system of temporary tracks on Hamilton Street from a connection at Tenth Street with the Willow Street Branch to the main line at Twenty-second Street, and from this point westward to shift the old tracks on Pennsylvania Avenue to the south side, so as to admit of the construction of the north wall of the tunnel, after which the temporary track was shifted to the extreme north side of the avenue, and supported in part upon the newly constructed wall. This allowed the south wall of the tunnel and the arches to be built. Railroad facilities were maintained with business establishments by means of sidings leading to the temporary track. The contract for the temporary tracks also included the erection of temporary freight houses at Thirteenth and Callowhill Streets, so as to allow the old buildings to be removed without interfering with traffic along the railroad. After the completion of the temporary tracks the work of underpinning the buildings on both sides of Pennsylvania Avenue was commenced and vigorously pushed. As the new tracks at Thirteenth Street cross about at the present grade, it is therefore necessary to lower this street about thirteen feet at Noble Street to avoid the grade-crossing. This lowering carries down with it portions of Hamilton, Buttonwood, and Callowhill Streets between Twelfth and Broad Streets. Many of the buildings along the line of Thirteenth Street required underpinning, the most important being the large building at the northwest corner of Thirteenth and Noble Streets, occupied by Stewart Brothers. All this work has been successfully completed, and the streets are being excavated. The Philadelphia Traction Company has a large conduit in Thirteenth Street, which, at the present time, is being supported upon piles, preparatory to lowering into its new position. The heavy retaining walls on both sides of the depressed yard between Thirteenth and Sixteenth Streets, including the bridge abutments at Broad and Fifteenth Streets, were all constructed in trench, and no serious difficulties were encountered.

The work on the south side of the avenue west of Fifteenth Street consisted of a retaining wall from Callowhill Street to Pennsylvania Avenue parallel to and forty-one feet distant from the warehouse, and forming the western end of the depressed yard. From the north end

FREIGHT YARD—WEST FROM BROAD STREET.

of this wall the main retaining wall passes on a curve under the northeast corner of the warehouse and extends to the south abutment of the Sixteenth Street bridge. At Sixteenth Street the face of the wall is fifteen feet from the south building line of Pennsylvania Avenue. It is constructed of ashlar masonry, and forms the south abutment of the railroad bridge connecting the high level tracks at Sixteenth and Hamilton Streets with the warehouse and the incline to the depressed yard. The warehouse is a large, heavily-loaded, six-story brick structure used for storing merchandise; its foundations do not extend to rock, and the whole front of the building was underpinned by rubble masonry founded on rock. This work has been successfully accomplished by underpinning in sections and by tunneling.

On the north side of the avenue the wall runs in a straight line from Sixteenth to Fifteenth Streets. For a distance of about 210 feet east of Sixteenth Street it is constructed of ashlar, forming the north abutment of the railroad bridge above described. From this point to Fifteenth Street it is of rubble masonry, forming the north bearing of the bridge portion of the driveway on Pennsylvania Avenue, by means of which industrial establishments have an outlet to Fifteenth Street. The fronts of the buildings occupied by Messrs. Edward Harrington & Sons and Goodall & Waters were removed, and a new front constructed with foundations extending to the bottom of the retaining wall. West of Sixteenth Street the work consists of the construction of a retaining wall fifteen feet north of the south building line of Pennsylvania Avenue, extending from Sixteenth Street for a distance of about 240 feet westward, thence by a 5.5 per cent. inclined wall to retain the approach to the new freight yard of the Philadelphia & Reading Railway Company and to connect by bridge across the avenue to the establishment of Messrs. William Sellers & Co., Inc.; on the north side of the avenue the entire front of the buildings occupied by Messrs. William Sellers & Co., Inc., between Sixteenth and Seventeenth Streets, was underpinned, and a retaining wall, approximately fifteen feet from the north building line, has been constructed. The adjacent shops of William Sellers & Co., Inc., contain a number of large and very sensitive machine tools, in many cases placed almost against the wall on Pennsylvania Avenue, the only foundation being a bed of concrete twelve inches in thickness and extending over the whole shop. There are eight columns in four pairs in the front wall, each pair carrying

View showing Underpinning.

the end of a runway upon which a very heavy traveling crane runs. These columns were underpinned first, new foundations being on rock, and the walls underpinned afterward in sections. Upon the completion of the underpinning the retaining wall was constructed. All this

UNDERPINNING PIER AT WM. SELLERS & CO.

work has been successfully done. All the retaining walls were built in trenches about thirty-three feet deep.

West of Seventeenth Street the work on the south side of the avenue consisted of the construction of a retaining wall with its face on the building line in front of property occupied by A. Whitney & Sons and Charles Fernberg. On the north side of the avenue two main

retaining walls were constructed, that on the south retaining the five per cent. grade connecting the Baldwin shops at this point with the subway and extending the full length of the block. This wall was located fifteen feet from the building line. The north wall is on the building line at Eighteenth Street, and, after descending under the carpenter shop, follows the curve of the connection within the yard of the Baldwin works. A temporary front was placed in the carpenter shop at Eighteenth Street back of the building line of Pennsylvania Avenue; the old front was removed, and the retaining wall built and the new front constructed with the wall for a foundation. At Seventeenth Street the front walls of the forge shop and boiler house on the north side were underpinned and the southernmost wall constructed. A coal vault, to replace the storage room destroyed by the change, was built close to the boiler house on the Baldwin property surrounded by masonry walls and covered by a steel beam construction carrying brick arches and the yard above. In constructing the east wall of this vault it was necessary to remove the west end of the boiler house including one boiler. All of this work has been completed in a satisfactory manner.

The work on the south side of Pennsylvania Avenue west of Eighteenth Street consisted in the construction of a retaining wall on the house line the whole length of the block. On the north side of the avenue, in front of property occupied by the Pickering Spring Company and a number of dwelling houses, the work consisted in the construction of a retaining wall fifteen feet from the north building line at Nineteenth Street, curving to the north for a distance of about 102 feet and return to the building line at right angles to the same. From this point the wall follows the building line of Eighteenth Street. Ten small houses fronting on Pennsylvania Avenue between Nineteenth Street and west end of the Pickering Spring Company's building have had their fronts removed. The five westernmost houses have been rebuilt. The work on the Pickering Spring Company's building consisted of placing a temporary front in the building and removing the old front; constructing a retaining wall on the house line and rebuilding the front for the same. In carrying on this work only half of the building was occupied by the contractor at one time.

The work west from Nineteenth Street embraced the construction

TEMPORARY FRONT FOR BALDWIN SHOPS AT EIGHTEENTH STREET.

of retaining walls, the reconstruction of buildings on the north side of the avenue occupied by Messrs. Stanley G. Flagg & Co., and other properties; and on the south side by the Philadelphia Grain Elevator Company and other properties. The work on the south side consisted of the removal of several sheds and buildings and the construction of two retaining walls; the south wall is on the south building line, and retains the earth south of the ascending grade for the connection to the grain elevator at Twentieth Street, ending at the east end of the elevator building. The north wall is about fifteen feet from the south building line, and extends the full length of the block and retains the approach on the north to the elevator. On the north side of Pennsylvania Avenue the main wall extends from Nineteenth to Twentieth Streets, with its face fifteen feet from building line. A length of seventy-two feet of this wall, situate at the west end of the property of Stanley G. Flagg & Co., has been omitted; through this space an opening is made from the grade of the subway into the property occupied by Stanley G. Flagg & Co., of sufficient size to accommodate a freight car, which it is the intention of the owners to elevate, by means of a hydraulic lift, to the present ground floor of their buildings.

The work west of Twentieth Street consists of the construction of retaining walls and reconstruction of buildings. Upon the property on the south side occupied by Messrs. Bement, Miles & Co. it was necessary to construct temporary fronts inside of the buildings, remove the present front walls and construct retaining walls upon the building line, and reconstruct the fronts of the buildings. Connection with this property will be made to the subway at two points—one under an extension of the machine shop, at Twentieth Street, and the other through an excavated yard at Twenty-first Street, at about the level of the subway. This work is rapidly approaching completion. The work on the north side consists of a retaining wall along the west building line of Twentieth Street from Hamilton Street to Pennsylvania Avenue, and along the south building line of Hamilton Street from Twentieth Street to the east portal of the tunnel, near Twenty-second Street. On the south side of Pennsylvania Avenue west of Twenty-first Street the work included the construction of two retaining walls and the removal of a portion of the ice-house and wagon-storage building of the Knickerbocker Ice Company, with the

TRENCH FOR SIDE WALL—WEST FROM TWENTY-SECOND STREET.

WEST FROM SPRING GARDEN STREET—LOCOMOTIVE TENDER LODGED ON FORTY-EIGHT-INCH WATER-MAINS.

reconstruction of the fronts of the same. The south retaining wall follows the general line of the five per cent. ascending grade for connection with the Knickerbocker Ice Company, and finally becomes

VIEW OF TUNNEL ARCH SKEWBACK.

the foundation of the new end of the wagon-storage building. The north wall follows the ascending grade of the connection, and supports the same; and, at a point east of Hamilton Street, it finishes east of the tunnel portal.

TUNNEL WALL SHOWING SKEWBACK IN POSITION.

The tunnel commenced at a point east of Twenty-second Street. It consists of a segmental arch, 52 feet span, 8 feet 8 inches rise; the crown is 22 feet above the top of the rail and the arch radius is 43 feet 4 inches. It is designed for four tracks. The arch ring is of brick, 3 feet thick at the crown and 4 feet thick at the springing line. Over the top of the tunnel and in the center of Pennsylvania Avenue are to be placed thirteen openings for ventilation; these are to be constructed of steel, carefully protected by a terra cotta covering. The visible opening in the street will be 10 feet by 47 feet 10 inches for twelve of the openings, and 10 feet by 78 feet for one. These openings will be surrounded, first, by a rustic masonry wall, 3 feet 8 inches in height, upon which vines will be planted; and around this wall will be a grass-plot, 6 feet wide, in which shrubs especially suited for the local conditions will be planted; around the outside of this will be an ornamental iron fence, protected by an 8-inch granite curb. The avenue itself over the tunnel will be 120 feet wide, and will consist of sidewalks 20 feet in width, the 6 feet nearest the curb being sodded and planted with selected trees. Between the main curbs, 80 feet apart, the street will be paved with asphalt on an 8-inch concrete base, the distance between the main curb and the ventilation openings being 27 feet on each side of the street. At the western end Pennsylvania Avenue widens out into a grand plaza opposite the Green Street entrance to the Park, where the beautiful Washington Monument is located. The advantages of this avenue for travel to the Park from Spring Garden Street and from Twenty-second and Hamilton Streets are obvious.

In the open subway west of the tunnel the retaining wall on the north side has been completed and a large amount of the excavation done, and the wall facing up the side of the B. & O. tunnel is nearly completed. The old B. & O. retaining wall northwest of the portal is being removed.

When the original plans of the tunnel were prepared, an artificial system for ventilating the same was devised, with side exhaust conduits, fresh-air intakes, and two fan stations. The fan stations were so located as to divide the tunnel into almost four equal sections, the station being located about the middle of each section. In each station there were to be two fans, of about 20 feet in diameter, to draw the gases from the tunnel through the openings, at intervals of about 150 feet, leading from the roof of the tunnel to the conduits; the latter

View of the Tunnel.

were to be located on the north side of the tunnel and parallel to it. The grade of each of the projected conduits was arranged so that any condensation would run to the fan stations, where it would be properly

GENERAL VIEW OF ARCH OF TUNNEL.

provided for. The conduits were to be 11 feet in diameter at the fan stations, decreasing to 6 feet 6 inches at the ends. The fans were to be driven by electric motors, and to discharge into stacks high

Bracing in Trench at Twenty-eighth Street.

enough to prevent any inconvenience to surrounding property. Each fan was to have a capacity of 150,000 cubic feet a minute, and the entire plant 600,000 cubic feet a minute, or about one-fifth of the

VENTILATION OPENING, SHOWING STEEL WORK.

entire cubic contents of the tunnel. It was thus expected that the entire contents of the tunnel would be replaced every five minutes. On the south side of the tunnel fresh-air intakes were to be provided,

each with an area of 35 square feet; they were to be connected on the level of the rail in the tunnel, and were properly protected by automatic shutters, to prevent any escape of the gases into the street.

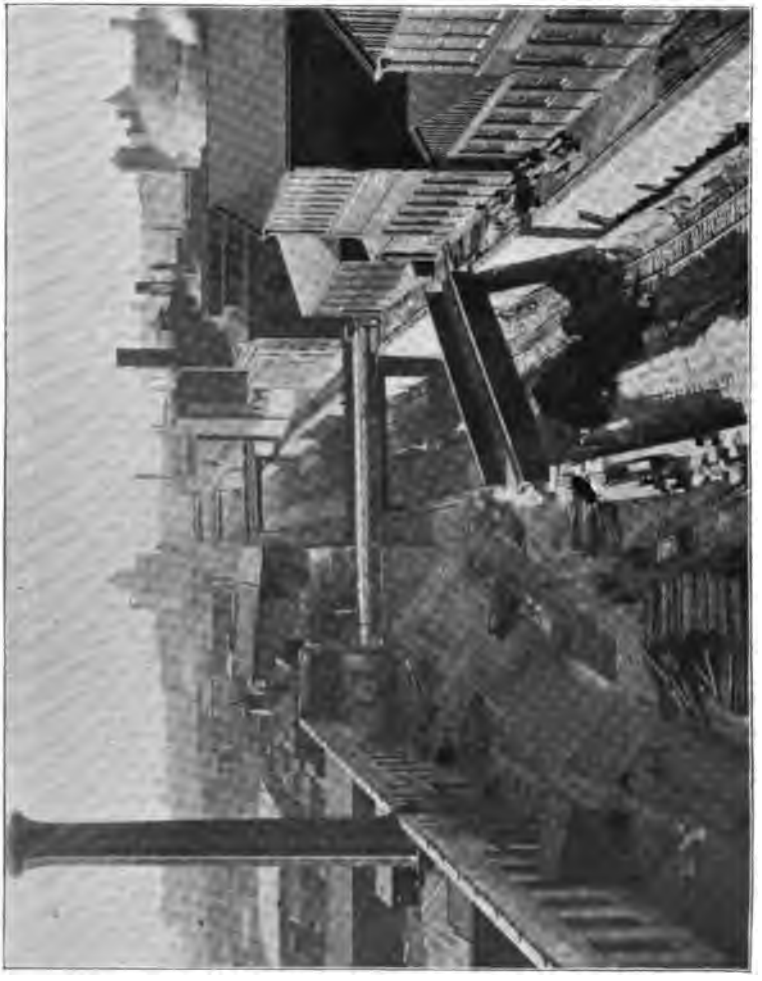
Owing to the expense of construction and maintenance this scheme was finally abandoned, and the one that is now being constructed was adopted.

In the carrying out of this work, numerous lines of water- and gas-pipes and electric conduits were encountered, entailing upon the bureaus and corporations having them in charge considerable work, and requiring great care and skill to prevent interference with the public service. At Broad Street it was necessary to lower the 20-inch, 12-inch, and 30-inch water-mains in the street, making them pass beneath the subway. A 24-inch gas-main was also carried under the subway, and four lines of 12-inch gas-pipe hung to the superstructure of the bridge. At Twenty-first Street a 48-inch and a 6-inch water-main were laid in tunnel on one side of the street, and a 24-inch and a 20-inch main in tunnel on the other side of the street. These tunnels were about 44 feet below the surface of the highway. Forty-eight-inch mains cross Pennsylvania Avenue on the line of Fairmount Avenue, Green Street, and Twenty-fourth Street, and at such an elevation as to interfere with the arch of the tunnel; it has therefore been necessary to reduce the diameters of the mains to allow them to cross. This has been accomplished by dividing the 48-inch main into two 36-inch mains at Fairmount Avenue, while at Twenty-fourth and Green Streets the diameter has been reduced by means of reducer cones on either side of the throat, using the principle upon which the Venturi meter is based. Mr. Fuller, Assistant Engineer of the Bureau of Water, has kindly consented to describe the work in detail.

Considerable thought and attention were given to the connection from the depressed tracks in the subway to the industrial establishments along the line. Owing to the fact that Noble Street and the tracks of the railroad cross Thirteenth Street by bridge, the connections east of Broad Street are maintained practically as at present. The connections with the Baldwin Locomotive Works and the freight-yard and warehouse at Sixteenth Street are to be made by means of inclines with five per cent. grades, operated by ordinary locomotives. The connection with William Sellers & Co. and the property formerly of Whitney &

General View East from Fifteenth Street.

Sons was arranged for on the original plan by means of a power lift having a capacity sufficient to raise a locomotive and three loaded cars at the same time—an aggregate weight of 420,000 pounds—from the



VIEW WEST FROM SIXTEENTH STREET, SHOWING SUBWAY AND BRIDGES AT STREET-CROSSINGS.

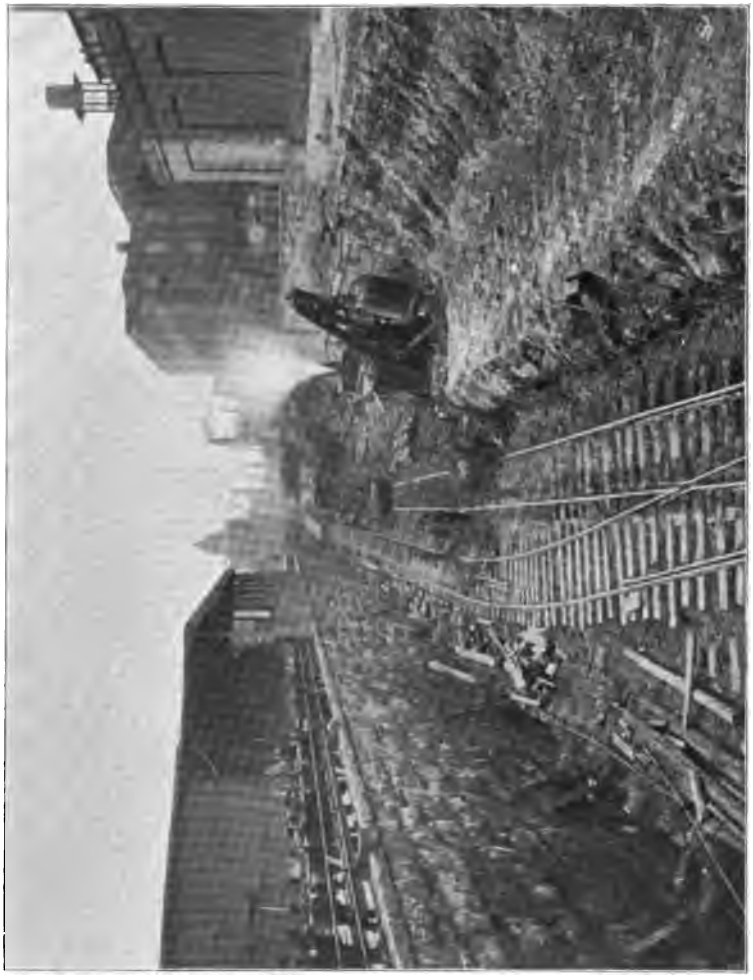
level of the depressed tracks to the present level. A bridge over the subway was provided to connect the north and south sides between Sixteenth and Seventeenth Streets. The Philadelphia & Reading

Railway Company having purchased the Whitney property, a five per cent. incline connecting with the originally contemplated bridge is now provided to keep up the connection with William Sellers & Co.

VIEW EAST FROM SIXTEENTH STREET, SHOWING FREIGHT YARD.

The works of the Baldwin Locomotive Company between Seventeenth and Eighteenth Streets, the elevator of the Philadelphia Grain Elevator Company, at Twentieth Street, and the Knickerbocker ice plant,

west of Twenty-first Street, are connected with the subway by means of inclines of four and five per cent. grades, operated by ordinary locomotives. The connections to the works of Bement, Miles & Co.



General View West from Seventeenth Street.

and Stanley G. Flagg & Co. are made from the lower level of the subway.

All of the bridges over the subway are constructed of steel, and are

of the plate-girder type, the entire superstructure being below the level of the street; they are all paved with asphalt—excepting the Fifteenth Street bridge, which is paved with vitrified brick—and have granolithic sidewalks.

The total weight of the bridges is 7,529,783 pounds, and of the vent openings 1,710,000 pounds, making a total of 9,239,783 pounds, or about 4600 tons.

In the depressed yard of the subway, between Broad Street and Thirteenth Street and Callowhill and Noble Streets, two brick freight-houses are being erected to replace the original buildings which occupied this site. The western halves of both buildings have been completed and in service since October 1st and the temporary freight buildings at Thirteenth Street demolished. The permanent tracks are being laid, and a portion of those east of Fifteenth Street are in service.

In the subway west of Fifteenth Street a coal-yard is to be constructed, and in the depressed yard west of Twentieth Street a brick freight-house, an engine-house, and a repair shop will be built; also a 50-ton electric traveling crane for the depressed yard, the erection of which will not be commenced until the excavation is completed.

The work of constructing the subway and tunnel has been carried on directly under the charge of the Bureau of Surveys, Department of Public Works, and the officers responsible for the carrying on of the work are Thomas M. Thompson, Director of the Department; George S. Webster, Chief Engineer of the Bureau of Surveys; George E. Datesman, Principal Assistant Engineer; Samuel T. Wagner, First Assistant Engineer Pennsylvania Avenue Subway; D. Jones Lucas, Second Assistant; and R. I. D. Ashbridge, Third Assistant. Joseph M. Wilson is the consulting engineer representing the Philadelphia & Reading Railway.

MOVEMENT OF WATER-MAINS IN CONNECTION WITH PENNSYLVANIA AVENUE SUBWAY WORK.

ALLEN J. FULLER.

Read October 15, 1898.

THE Pennsylvania Avenue Subway, now in course of construction in the heart of the city, extends west from Thirteenth to Twentieth Street, and thence in a northwesterly direction to Twenty-ninth Street. The lines of construction vary in width from 100 to 300 feet, and in depth sufficient to allow head room for the construction of bridges over the subway at each street crossing the line east of Twenty-first Street, and likewise the masonry tunnel from east of Twenty-second Street to northwest of Fairmount Avenue.

The line of this great work is crossed by thirty-two water mains, including eighteen service mains, twelve supply mains and connections, and two pumping mains, all of which either have been, or are required to be, moved from their original positions, with the exception of one 20-inch and one 48-inch supply main crossing at Spring Garden Street.

The 20-inch and the 30-inch mains in Broad Street were depressed to subgrade after the construction of the bridge abutments and previous to the excavation of the roadway.

The 6-inch main in Fifteenth Street has been permanently removed, as on this street the subway occupies the whole space from Callowhill Street to Noble Street.

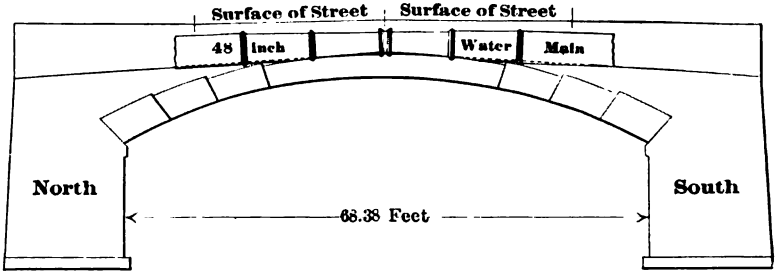
The mains in Sixteenth, Eighteenth, Nineteenth, and Twentieth Streets will be suspended from the bridges spanning the subway at these points, and the main in Seventeenth Street will be crossed at subgrade.

The four mains at Twenty-first Street and Pennsylvania Avenue were required to be relaid at subgrade previous to the excavation of the new roadway in Pennsylvania Avenue, and in order to accomplish this two tunnels were driven, in rock, between the bridge abutments, parallel with the line of Twenty-first Street, 167 feet in length, about

eight by nine feet in the cross-sections, and in depth from thirty-six to forty-one feet below the surface of the street.

The various castings used in the relaying of these mains were lowered into the tunnel-shafts and then railroaded into their proper positions. The ends of each line of pipe extend through arches in the bridge abutments, whence they ascend to the level of the original lines to which they have been connected, and since which connection the intervening sections of the old pipes have been removed.

From Twenty-second Street west the pipe-lines cross the subway over the tunnel; but some difficulty has been encountered with the work at Twenty-fourth Street, at Green Street, and at Fairmount Avenue, owing to the insufficient space between the tops of the arches and the street surfaces in which to lay the 48-inch mains at these



Cross-section of the Pennsylvania Avenue Subway Tunnel, at Twenty-Fourth Street; Showing the 48-inch Main Reduced at the Center of the Arch to Thirty Inches in Diameter.

points. At Fairmount Avenue two lines of 36-inch pipe were substituted for the 48-inch main, and by partially embedding the former in the masonry of the arch they were laid at a depth sufficiently low to allow the space necessary for paving.

After carefully studying the matter and making a number of experiments to determine the best plan to be adopted for carrying the 48-inch main over the tunnel at Green and at Twenty-fourth Streets, it was decided to gradually reduce their diameter from 48 inches at each side of the center of the tunnel to 30 inches at the center of the arch. The east 48-inch main in Twenty-fourth Street has been equipped with a reduced pipe of this description. It is 36 feet 7¼ inches in length, horizontal on top, with the bottom 18 inches higher at the center than at the ends, which gives sufficient rise for this sec-

TWO 48-INCH MAINS CROSSING PENNSYLVANIA AVENUE SUBWAY AT TWENTY-FOURTH STREET.
REDUCED SECTION (48 X 30 X 48 INCHES) IN MAIN ON LEFT.

tion to straddle the arch and still be low enough to allow room for the street paving.

The ratio between the throat, or reduced section, and the main is as 1 to 2.51. The difference in head due to the velocity in the throat and that in the main was ascertained with mercury columns, from which the following discharges were computed, and for which the corresponding loss of head due to contraction of the pipe is given, as indicated by piezometers:

No. of Test.	Throat Velocity in Feet a Second.	Discharge in 24 Hours. Million Gallons.	Loss of Head. Pounds.
1, ...	4.504	14.3	.018
2, ...	6.777	21.5	.044
3, ...	10.111	32.0	.100
4, ...	11.287	35.7	.133
5, ...	13.450	43.6	.182
6, ...	14.358	45.5	.184
7, ...	14.767	46.8	.213
8, ...	16.381	51.9	.233

From the above-given results it would appear that, in this case, the loss of head due to the reduced bore of pipe is so slight that there can be little objection to the adoption of this method for crossing obstructions in the line of water- or gas-pipes or sewers. Care must be observed, however, in proportioning the throat or reduced area to the maximum required capacity of the conduit; otherwise this arrangement will prove unsatisfactory when discharging at a high velocity.

From the beginning of the subway construction, including the excavation and construction of the retaining walls, and during all the blasting and handling of heavy materials (frequently close to the pipes buried in the ground, exposed on the surface, or supported on trestles high in the air) there has been but one accident to the water-mains, and this a very slight one. The alterations made in the lines of water-pipes have progressed without any mishap, and, it might be added, without anxiety except for the possibility of an accident to some of the mains upon which the whole lower section of the city depended for its supply. The immunity from accident and the steady, even progress of the work are entirely due to the precaution and care of the contractors engaged upon the construction of the subway, and to Mr. John Montgomery, Purveyor of the Fourth District, who was actively in charge of all alterations made to the pipes connected with the subway.

DISCUSSION.

THE PRESIDENT.—Those who have the pleasure of being brought into contact with Mr. Webster know that he is an extremely busy man, with every hour of his official day filled. I do not know when his official hours end, but it is certain that they do not stop with the closing of the doors of the City Hall. Knowing that to be true, he has placed us under a double obligation; first, for the great value of the paper so ably presented to us, and secondly, for that inroad into his time and well-earned leisure which otherwise might have been applied to rest and recreation. The last is no small part of our obligation to him. I wish to ask if the thickness of the walls in the covered section differs from that in the open section, and what ratio would the mean thickness bear to the height of the retaining walls?

MR. WEBSTER.—The side walls of the tunnel are slightly thicker than retaining walls of the same height, but vary somewhat according to the nature of the backing. Where hard rock was found back of a retaining wall the wall was built of a minimum thickness of six feet. This was done because it was found that a wall of proper character could not be built of less dimensions. The ratio of the mean thickness of the wall to its height is about 47 : 100. This we worked out by experience, and found it to give a very good section.

MR. FULLER (in answer to questions).—While raising or lowering water-pipes which are in service, especially in the case of large mains, there is always more or less movement at the joints and a corresponding leakage therefrom; but during the period of raising or lowering, little or no attention is given to this leakage unless it indicates the probability of the lead joint being forced out bodily. In such case the joint is recaulked sufficiently to make it secure while handling the pipe. After the main has been placed in its new position, all joints are carefully recaulked. I would like, Mr. President, to have the opinion of the members on the advisability of using a contracted pipe, such as I have described; also as to the accuracy of the results obtained by the method adopted to measure the discharge. If contractions in water-pipes can be thus made without causing serious loss of head, it would be useful in many cases to avoid underground structures in city streets.

THE PRESIDENT.—Mr. Fuller has opened a very interesting subject, and I suggest that we set aside one of our conversational meetings for discussion of the measurement of the velocity of water in closed conduits. I am sure that we could have an interesting discussion on it, but it is too late now to take it up. Mr. Webster alluded to a point about which I would like some explanation. The arch seemed to be divided generally into four rings, but at intervals in the cross-section of the arch there seemed to be a break in the bond.

MR. WEBSTER.—It is built in rings, and at radial sections is bonded across, one ring above another; a brick is gained in each third course. It is believed in this way that better results are obtained and the arch bonded as one. When arches have been constructed in concentric rings, in keying them sometimes one course is keyed better than another and the loose ring drops out. The plan we pursued is called by some authors "the Philadelphia bonding." It has worked very successfully in all our arch and sewer constructions.

A PROPOSED WATER-POWER IMPROVEMENT IN THE GORGE OF THE NIAGARA RIVER, NEW YORK.

JOHN BIRKINBINE.

Read January 7, 1899.

In May, 1898, a reconnaissance of the Gorge of the Niagara River, New York, made in company with Mr. George A. Ricker, C. E., of Buffalo, who planned and constructed the Niagara Falls & Lewiston Railroad, known as the Gorge road, was undertaken for the purpose of determining the practicability of utilizing for power a portion of the water which, rushing through the gorge, forms the famous Whirlpool Rapids. The detailed examinations were made upon the American side, or east bank of the river, between the International Railroad bridges (formerly Suspension Bridge) and the foot of the rapids, near Lewiston, a distance of 5.4 miles.

The Niagara River, which connects Lake Erie and Lake Ontario, falls, in a distance of thirty-seven miles, 333 feet. Of this fall, one-half is the vertical drop over the Canadian or Horseshoe Falls, 2400 feet wide, and the American Falls, 1000 feet wide.

The profile of the river, as given in volume XVI, Tenth United States Census, part I, is as follows:

Falls from Buffalo to the head of the Upper Rapids,	20 feet
Fall in the Upper Rapids,	53 "
Average of vertical fall,	160 "
From Niagara Falls to Lewiston, including the Lower Rapids, is	98 "
From Lewiston to Lake Ontario there is a fall of	2 "
Total,	333 feet

The average flow is variously estimated at from 166,600 to 275,000 cubic feet per second. This volume, passing through the gorge with a width of from 300 to 400 feet, has worn a deep channel, in which the water attains an enormous velocity.

To determine approximately this velocity, large floats, dropped from the bridges, were timed, and it was found to be, at normal conditions,

PORTION OF NIAGARA GORGE, SHOWING ON THE RIGHT THE CLIFFS ON THE AMERICAN SHORE, BELOW WHICH IT IS PROPOSED TO LOCATE THE CANAL, THE ENTRANCE BEING NEAR TO THE LOWER RIGHT-HAND CORNER, THE POWER-HOUSE JUST AROUND THE FARTHEST POINT ON THE AMERICAN SIDE. THE N. F. & L. R. R. IS ALSO SHOWN.

21.75 miles per hour from the bridges to the whirlpool. But opposite the Buttery Elevator the surface velocity was 25.5 miles per hour.

It may not be practicable to utilize the entire fall (ninety-eight feet) between the extremes named, but the major portion of the declivity of the river can be applied advantageously by two power stations, one placed near the outlet of the whirlpool, and one at the foot of the lower Whirlpool Rapids.

The gorge is somewhat wider below the whirlpool than above it (there being more talus, owing to the cliff faces receding further from the river), and with shallower water near the shore a canal of greater average width is practicable.

Beyond a general investigation as to the possibility of supplementing the power which can be developed by the upper Whirlpool Rapids, with additional power from the lower Whirlpool Rapids, the latter project has not been considered for immediate improvement, the study of details being confined to the practicability of obtaining power on the American shore from that portion of the river between the International Railroad bridges and the whirlpool outlet.

The plan of improvement proposed is to divert a portion of the water from the river below the bridges into a canal, separated from the stream by an embankment or wall, which will also carry the roadbed of the Niagara Falls & Lewiston Railroad. Owing to the velocity of the river, and to provide for variations in the water level, it is proposed to construct an entrance which will practically be a monolith of concrete, or a mass of masonry, pierced with openings through which the water can pass into the canal, and to continue the berm-bank to such height as will provide for the maximum flood level in the gorge. About 1400 feet below the entrance controlling gates will be placed in the canal, waste ways being located between the entrance and the gates to relieve the canal of excess water passing through the entrance.

Between the points selected for the inlet to the canal and for the discharge from the water-wheels, the Niagara River has eroded a channel varying, at water level, from 200 to 270 feet below the plateau. In places the wall of the gorge extends nearly vertically to these heights; in others there is a vertical escarpment near the top and talus slopes below; in others there is the top escarpment and an intermediate bench or benches. Debris resulting from erosion

VIEW (TAKEN DURING THE CONSTRUCTION OF THE N. F. & L. R. R.) NEAR THE POINT SELECTED FOR THE ENTRANCE TO THE CANAL, SHOWING THE CLIFFS, ROCK-BENCHES, AND TALUS.

has created talus of greater or less extent on the benches and near the base of the cliffs.

A critical examination of both sides of the river suggests that, except in a few localities, where the action of the current has been so confined as to undercut the softer rocks, this debris rests upon a series of receding steps, from the water back to the lines of vertical escarpment.

To excavate a canal through this talus, and, where necessary, through the benches of rock, will require the handling of quantities of material so great as, under other conditions, to discourage the effort.

But the talus can be removed at low cost by hydraulicking, washing the finer and softer material and the smaller boulders away, and leaving the hard, large boulders and the rock *in situ* exposed. Subsequently, owing to the isolated location of the gorge, the absence of improvements other than the Niagara Falls & Lewiston Railroad, and the possibility of economically using explosives to dislodge large masses, this material can be handled cheaply.

The river can be depended upon to receive the waste material, and much of the harder and better rock can be utilized in the construction of the inlet, gate chambers, and berm-bank for the canal, for building the power station, etc.

The limited space between the cliff walls and the river restricts the width of the canal between the entrance and the gates, and necessitates a velocity of flow in excess of what is required below the gates, with corresponding absorption of head, but the declivity of the water surface of the river in this distance will permit of locating the gates beyond the flood level. This method of construction for the first 1400 feet of canal will reduce the expenditures upon the remaining portion and upon the gates, and will admit of securing a larger cross-section of canal below the gates at comparatively small outlay.

After several months spent in studying the problem, it was decided to estimate for a canal which could deliver 10,000 cubic feet per second, at moderate velocity, except at the portions specified. This quantity represents but five per cent. of the normal volume which is estimated as passing through the Niagara Gorge. Making allowances for head lost in the canal, and for efficiency of water-wheels, this volume of water can, with the fall available, produce 35,000 horse-power.

The present project considers the water as taken from a point about

NEAR VIEW OF THE CLIFFS, PROJECTING ROCK-BENCHES, AND THE DETRITAL MATTER FORMING THE TALUS.

300 feet below the bridges, from which point a fall of 45 feet to the outlet of the whirlpool can be secured by a canal 5300 feet in length, and it is possible to increase this fall to 50 feet or more.

To arrive at an estimate of the cost of constructing the canal, 44 cross-sections, extending from the top of cliff to the river, between the bridges and the whirlpool, have been carefully calculated in order to determine the apparent quantities of materials to be moved. The cost of handling this material is estimated in excess of that required for the removal of large quantities demanded in the construction of the Niagara Falls & Lewiston Railroad; for the excavation of the canal prism an additional amount is added, and where there is reason to anticipate pervious bottom or sides in the canal, where masonry walls are not placed, protection by puddle or planking is provided.

During the spring of the present year about 14,000 cubic yards of rock were broken from the cliffs at a cost below twenty cents per cubic yard,—a cost which, Mr. Ricker asserts, approximates that which prevailed in the construction of the railroad. The bulk of the berm-bank can be constructed of rubble, but portions of it will be of ranged masonry or of rubble faced with ashlar, and other portions will be carried on cribbing.

It is proposed to locate a power-house just below the outlet of the whirlpool, to equip it with water-wheels and electric generators, exciters, etc., and to carry the railway track over a portion of this power plant in order to allow free vent for tail water without interfering with the scenic features of the railroad.

The installations of wheels and dynamos may be made in units sufficient to meet the requirements of the business as it develops, but it would be economy to construct a canal of the maximum dimensions as the initial work; and although it is possible subsequently to erect a portion of the power-house, it is believed to be also advisable to complete this at once.

The recognized charge for continuous power in large units at Niagara Falls is twenty dollars per annum for one electric horse-power delivered to local manufacturing plants, or twelve dollars per annum for one dynamic horse-power delivered on water-wheel shafts at power stations.

From the estimates made, the proposed plant in the gorge of the Niagara River will be able to produce power so as to compete at prices considerably below those now charged, and as the demand approxi-

mates the maximum capacity of the canal, the cost per horse-power may be rapidly reduced.

A calculation making allowance for sinking fund, administration, taxes, franchises, and other expenses indicates that when 10,000 horse-power is demanded the proposed plant could compete without loss at the present rates charged for power at Niagara, and that as the requirements increase and more power is supplied the possible profits will be largely augmented.

Whatever advantages the vicinity of Niagara Falls possesses for the utilization or for the distribution of power are as applicable to that produced in the Niagara Gorge as to that obtained from the vertical fall.

The Niagara Power Company employs a short headrace, but the deep wheel-pits and long tail-race tunnel were very costly to build. The gorge improvement may require the handling of as much excavated material, but the expense of removing this from a side hill into a rushing torrent will be small as compared with the pit- and tunnel-excavation of the Niagara Power Company.

The excavation of the canal or headrace of the Niagara Falls Hydraulic Power and Manufacturing Company through valuable lands in the heart of the village, and the removal of the excavated material, will also be more costly for a given volume than for the gorge improvement.

In each of the present installations long, heavy penstocks or flumes and the special construction required for wheels and generators have greatly augmented the cost.

While the volume of water required in the gorge improvement as proposed will be greater for a given power, the head is moderate, and wheels and connections will be more nearly within the proportions of general practice.

THE RECONSTRUCTION OF THE YORK, PENNSYLVANIA, WATER-SUPPLY.

JOHN BIRKINBINE.

Read January 7, 1899.

THE city of York, Pennsylvania, has had a public water-supply since 1816, when water from a spring was conveyed two miles through wooden pipes to a reservoir, located in what is now the residence portion of the city; the water was also distributed through wooden pipes. Subsequently, pumping from the Codorus Creek, by water power and later by steam power, in addition to the water power, supplemented the gravitation supply and the reservoir capacity was added to.

It would be interesting to trace the growth of this public supply and indicate the many changes which have resulted in eight decades, but this is not intended as an historical paper. Its purpose is primarily to describe the method followed in correcting defects in a reservoir,—a problem more troublesome to an engineer than the design or construction of a new work,—and incidentally to describe the present plant. Some facts concerning the reduction of stream pollution will also be presented.

In the year 1896 the York Water Company maintained two pumping stations on the Codorus Creek, two reservoirs having an aggregate maximum capacity of 10,000,000 gallons (which received water from the pumping-stations and from the spring mentioned), and 40 miles of distributing pipes. These reservoirs were too low for the requirements of the extended city, for although the lower portions were from 65 to 105 feet below the full water-line, some of the newer streets approximated the level of water in the reservoir, and it was necessary for residents in a few localities to obtain a supply by means of hand-pumps connected to the town distribution.

Long lines of pipe of small diameters also aided in restricting the service in remote sections, and in numerous cases pipes were fed by others of smaller diameter.

In the gradual growth of this distribution a variety of cast-iron pipes were used (some of local manufacture), and many of the older pipes were cast on the side in 6-, 7-, and 9-feet lengths, later additions being of the standard 12-feet lengths cast on end.

So far as known, the diameters of the cast-iron pipe used included 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 20, and some 24 inch.

There was also a corresponding variety of valves, fire-hydrants, etc., representing the changes in water-supply equipment in eighty years.

The reservoirs having a limestone foundation gave considerable trouble, and a number of serious and expensive leakages resulted.

(Before describing the new work, I may be pardoned for referring with satisfaction to the continuous operation for forty-eight years of a pair of pumps designed and constructed for the York Water Company by my father, the late H. P. M. Birkinbine. The mechanism consists of two inclined pumps 12 inches in diameter and 24-inch stroke, geared through a master wheel to a water wheel and also to a high pressure slide-valve steam engine. These pumps, although in daily use from June, 1850, until the latter part of 1897, are in condition for additional service under the head due to the old reservoirs, and an offer to purchase them for resetting has lately been made.)

An increase of population and manufacturing industries threatened the character of the water obtained from the old stations, and realizing that a practical reconstruction of the water-supply was a necessity, the York Water Company provided for radical changes, and in 1897 commenced the construction of an entirely new system. A new pumping station was placed upon a branch of the Codorus Creek, two miles above the city, and in this station were installed two triple expansion duplex Worthington pumps, each of 5,000,000 gallons daily capacity, supplied by steam from two Zell water-tube boilers, each rated at 125 horse power.

A 24-inch pumping main 10,900 feet long was laid from the pumping station to the site of a pair of reservoirs which were intended to have a combined capacity of 40,000,000 gallons. The profile of this pumping main shows that irregularities in elevation were preferred to changes in horizontal direction, with the result that air traps are formed and an avoidable summit 40 feet higher than the

reservoir surface places a constant duty upon the pumping machinery in excess of what is actually required.

The elevation of the full water-line of the new reservoirs above the source of supply is 245 feet, but owing to the intermediate summit referred to the pumping machinery works against a static head of 285 feet plus friction in the pumping main.

On October 1, 1897, the new work was advanced as follows:

The pumping machinery was in place and had been in operation; the pumping main was laid and in use; one compartment of the reservoir was connected by a 20-inch main with the old reservoir, from which the city was supplied through the distributing system mentioned above.

The new pumping machinery was not in continuous service, but alternated with the old pumps in supplying the city; all the water used, however, was supplied through the old reservoir which gave average pressures from 30 to 40 pounds in the business section, but gave little, if any, pressure in some portions of the city; while the new reservoir when directly connected would supply this business section with water under pressure of from 95 pounds to 105 pounds and greatly improve the supply in other districts.

In the latter part of September, 1897, the York Water Company invited my assistance to decide how the new reservoir, which failed to hold water, could be made secure, and subsequently placed the work in the hands of myself, as chief engineer, and Mr. Henry Birkinbine, as resident superintending engineer. In the work of reconstruction my brother and myself cooperated; and the use of the pronoun *we* will be understood as indicating our joint views or action. In fact, the burden of detail, the important feature of reservoir construction, came upon the resident engineer. The approach of winter and the uncertainty of the old reservoir remaining in service, owing to a severe leak which developed at that time, demanded immediate action to secure some storage capacity.

An examination of the work done on the new reservoir resulted in a practical condemnation of what had been attempted, and failing to secure satisfactory cooperation from the contractor, the work of reconstruction was undertaken on Company's account. The condition required that this be carried out by day's-labor under the immediate supervision of the resident engineer. To avoid possible criticisms

from the contractor's bondsmen, it was decided to adhere as closely as practicable to the original proportions of the reservoir and to utilize as much of the work already done as could be accepted.

That the condemnation of the work was not too drastic a measure was demonstrated by subsequent discoveries.

The locality selected for the reservoir was one demanding special care in construction, for the hill upon which it was placed is one of a range formed of hydro-mica schists which define the limestone valley in which York is situated; in fact, limestone is found half way up the slope of the reservoir hill. The schistose foundation is in multitudinous layers, from the thickness of a sheet of paper to, in a few cases, two feet. These layers generally have a steep dip into the hill, but there are folds in which the stratification changes its direction or is vertical, or nearly horizontal, and in these folds the harder strata, generally quartzites, were often fractured transversely. Over this treacherous, seamy, and uncertain foundation was the surface earth, averaging about ten feet in thickness, evidently largely the result of decomposition and weathering of material similar to that described. The variation of the schist in color was almost as great as in thickness or hardness of the strata. This certainly will not be recognized as especially desirable material in which to excavate the basin of a reservoir, and its adaptability was not improved by harsh treatment resulting from heavy charges of high-power explosives.

The design and construction of the reservoir were evidently based upon the assumption that all that was necessary was the excavation of a cavity in the sloping hillside, depending primarily upon the assumed impermeability of the material *in situ* to hold water, and providing a rubble masonry core wall laid in cement in the center of the embankments. Although the specifications covered puddle and concrete "if deemed necessary," the amount and character of these in place and the wording of the specifications indicate that the above assumption covers the theory upon which the reservoir was planned; it certainly represents the practice followed in construction up to the time we took charge of the work.

The west compartment of the reservoir which the contractor had attempted to put into service had clayey earth and muck placed upon the bottom as puddle, but none on the side slopes. A portion of the bottom and portions of the sides were covered with so-called concrete,

the sides being riprapped with irregular stone, much too small and too loosely laid to be of any real service in a climate subject to the formation of ice in winter. There were numerous interstices between stones which would have formed ample accommodation for muskrats to enter holes which they could rapidly excavate.

The material upon the bottom was not such as could be accepted as good puddling, much of it being muck, and what was rated as concrete, had so little adhesion that it was impossible to obtain a sample block, the stones separating like road metaling when attacked by bar or pick. The too liberal use of high explosives had broken up and seriously disturbed the laminated slippery rock in which the excavation was made, and some of the filling and embankment showed evidence of imperfect compacting. The core wall, as constructed, was not impervious, and at one corner the puddled bottom of the reservoir was practically at the natural surface level.

An attempt had been made to store 20,000,000 gallons in the excavation made in the seamy rock above described, with only selected earth (not puddle) covering the rock at the sides, and with a bottom formed of inferior clay, from which top-soil, roots, and vegetable matter had not been removed, the thickness of the clay lining ranging from 9 to 20 inches.

Where the rock had appeared specially treacherous, a cover of concrete (so called), 6 to 13 inches in thickness, had been placed upon twenty-five per cent. of the bottom and fifteen per cent. of the side slopes, but this concrete was in disconnected patches, protected only by inferior riprap. The reservoir, as described, was expected to hold water to a depth of 30 feet. It failed when less than one-third full.

The discoveries mentioned demonstrated the necessity of a thorough examination and practical reconstruction, and it was evident that the entire western reservoir could not be repaired for service in the limited time before severe weather would necessitate suspending operations. Owing to the treacherous condition of the old reservoir, it was decided to divide the west compartment of the new reservoir by a cross-embankment and carry the work forward in the northern part of this as long as the weather would permit.

As a further safeguard, a water-tank 25 feet in diameter and 30 feet high was placed at a summit of the pumping main nearest the reservoir, the purpose of this being to have a reserve of 100,000

gallons of water in case the partial reservoir could not be put into service, and because of the complication resulting from the bottom of the old reservoir giving way. The method of repair suggested by the resident engineer, however, kept the old reservoir tight and made the use of the water tower unnecessary except as a relief to the pumping machinery.

In plowing up the condemned puddle on the bottom of the new reservoir to secure a base for the transverse embankment, a team of mules drawing a plow floundered into a large hole loosely filled with quarry refuse, and several similar defects were subsequently discovered in other portions of the bottom which had been considered as finished. Fortunately, the water which had been placed in the west compartment did not enter from the influent, which was merely a pipe projecting through the riprap, unprotected by apron of any kind. The water was backed in from the effluent pipes, an investigation of which showed them to have been placed without baffle walls, and it was discovered by crawling through the effluent that each joint was defective. Providence had evidently prevented the entire destruction of the reservoir.

To facilitate the operations of reconstructing the reservoir a series of electric lights were installed, a tram road one-half mile in length was constructed to a satisfactory deposit of clay, and a steam hoisting plant was put in place. By employing a large force of laborers, working night and day, the division embankment was constructed (in the meantime the portions of other embankments forming the small temporary reservoir being examined and compacted); subsequently the bottom and sides were puddled so as to hold water to a depth of twelve feet before severe weather stopped operations.

Late in December, 1897, water was admitted into this temporary section of the west reservoir, upon the bare puddle, without covering of any kind, and the city was supplied through this reservoir for ten months. With twelve feet depth the storage of this temporary reservoir was 3,500,000 gallons—sufficient to relieve the directors of anxiety during the winter months. The use of clay puddle without surface protection is not recommended, nor would it have been attempted except for the existing conditions, which required that storage as large as possible should be promptly provided. Work was prosecuted as long as it could be done with safety.

After the water had been drawn from this temporary reservoir an examination of the puddle was made. The surface for a depth of 1½ to 2 inches was soft, but considerable force was necessary to press a sharp round-end shovel its depth into the clay, and the material at the shovel's point appeared as dry as when first put into place, although for ten months twelve feet of water had rested upon this puddle.

Beyond some slushing on the sides, due to the action of wind, frost, and ice, the puddling stood remarkably well; repeated examinations and tests, checked by pumping records, failing to indicate any leakage whatever, which is accepted as a vindication of the decision to depend upon the use of good clay, well compacted, as a means of forming an impervious reservoir lining. This decision was the result of careful consideration which we jointly gave to the use of clay, concrete, asphalt, etc.

While this portion of the reservoir was in temporary use, work was prosecuted upon the balance of the western compartment, but it became evident, owing to the shattering of the schistose rocks by heavy charges of explosives, that it would be necessary to lengthen this compartment. To compensate for this the eastern compartment was shortened and widened, to utilize in the best manner the excavation and embankments already made.

The best portion of the rock removed was laid as a support to the core-wall in the division embankment, which indicated weakness, and was built against and over the unfinished core-wall of the eastern reservoir. This work was laid dry and was grouted with clay. Where the rock in place in the excavation showed open seams, these were cleaned out and grouted with cement, and the disturbed strata, in each compartment, were faced with stone laid in cement, and stepped back to correspond with the inner slopes. The dry stone walls in the east compartment were liberally protected with selected earth, well compacted, to form the inner slopes, and subsequently these slopes, as well as those of the masonry walls and the bottom, were, when properly dressed to form, covered with puddle.

In compacting the earth banks and the puddle no heavy rollers were used, but a number of one-horse rollers made of a series of independent wheels were employed. Our experience in reservoir construction favors the practice of spreading material thinly by shovel, and constantly rolling it with light, grooved rollers, instead

Proceed
Flow Wall
Flood Plain

of applying the material in layers of specified thickness and depending upon a heavy roller to compact the banks and puddle. The steam-excavator, the heavy steam-roller, and the dump-car hauled by locomotives seem in keeping with this progressive age—as we delight to designate the present; but failures too familiar to us all, where these did not secure good reservoir embankments or satisfactory puddling, will excuse an engineer for using the hand-shovel and horse-roller, even at increased cost of construction and risk of acquiring a reputation for "old fogyism."

The function of reservoir embankments and the excavated portions is to sustain the impervious lining; and it is primarily important that the integrity of these should be assured.

This assurance can only be obtained by constant vigilance and rigid attention to minor details. Apparently insignificant defects may develop into serious imperfections; for a leak of water through earth-work seldom decreases—the chances are that it will constantly increase. A reservoir is designed in an engineer's office, but its construction requires persistent and critical attention outside. The embankments are called upon to perform their full duty as soon as the reservoir is filled with water; therefore the less chance there is of subsequent settlement, the better.

If imperfect compactment during construction is permissible in any case, it certainly is not in structures lined with concrete or other rigid materials which can not follow moderate settlement, as clay puddle and brick lining may without material damage, thus indicating the location of any depression.

In constructing the embankments, as in placing puddle in the York reservoir, care was used to remove foreign material; all horse droppings, sticks, etc., were discarded, and stones were either placed in walls or assigned to the outer slopes. The softer schists were crushed under the rollers, and made satisfactory embankments. During construction, water was applied sparingly to the earth placed in embankments, and to clay in puddle, so as to keep the materials merely sufficiently moist to pack thoroughly; and the practice followed produced a mass into which a wooden surveying stake could be driven only after an opening had been made with a crowbar. When the puddle was in position, compacted, and dressed to the proper slope or level, it was covered with coarse sand, made by crushing some of the

harder rock excavated, and on this sand hard, red brick were laid dry. No cement was used in laying the brick except in forming the inlet aprons, the effluent supports, the skewback at the bottom of the slopes, in finishing the top coping, and in dressing up inequalities.

The bricks in the bottom were lightly grouted with cement, not to produce impermeability to water, but to fill voids which would harbor cray-fish or other aquatic animals which burrow in the sand in the bottom joints, and to make such burrowing difficult.

On the side slopes bricks were laid on the edge; on the bottom they were laid on the flat. The water rests upon the bricks, which are separated from the clay lining by three inches of sand; this clay lining (which is 2 feet thick on the bottom, decreasing on the slope from 2 feet to 1½ feet) is depended upon to make the reservoirs impervious, but in the portion of the embankment which was constructed, a conscientious attempt was made to give this puddle a firm support, and to protect any weak points which were apparent or suspected. Diligent search was made for such weak points, and unless some exist in portions of the work which could not be exposed without unwarranted cost, there seems no reason to anticipate any leakage in the reservoir lined with clay and brick.

The effluent pipes which were laid in the western reservoir were recaulked from the inside, but were not disturbed, as to do this demanded the removal and reconstruction of the entire embankment at that point. Baffle walls, however, were built and puddle liberally used about the pipes.

In providing for withdrawing water from the eastern reservoir we decided upon an effluent laid against the inner slope. This consists of a series of 42 pipes fitted with 3 sliding gates so as to draw water at 4, 12, or 20 feet above the bottom; removable screens being placed within the pipes. A drain-valve, operated by rod and lever, is also placed in the bottom. To utilize the head due to the summit between the pumping station and the reservoirs, and to improve the water by aëration, a mushroom fountain was erected, which is connected with the pumping main, and also by pipes with each reservoir. There is also a connection provided between the east and west reservoirs.

An interesting but annoying feature incidental to the reconstruction of the York water-supply was applying the augmented pressure from the new reservoir to the distribution, all of which had been laid

to withstand the limited head from the old reservoir, and much of it imperfectly connected.

This duty devolved upon the resident engineer, who had frequent verification of the fact that the maximum pressure is reached between

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to withstand the limited head from the old reservoir, and much of it imperfectly connected.

This duty devolved upon the resident engineer, who had frequent verification of the fact that the maximum pressure is reached between 11 P. M. and 6 A. M., generally about 2 A. M., when the demand for water is least and rest is most welcome to the manager.

The change of pressure was made gradually by districts, and, as was expected, there were numerous calls for repair gangs. In some instances pipes split; in others, pieces were blown out of pipes; plugs or fire hydrants imperfectly secured, defective valves, and joints poorly caulked were also promptly discovered. The damages to the house services and connections were, however, much less than anticipated, as it would not be surprising to find numerous defects developed in plumbing which was subjected to pressure for two to two and one-half times that which existed when the work was done.

To diminish the risk to house service and connections, the York Water Company supplied regulating valves, which were placed at cost for any water consumer who made application. A large number took advantage of this, and thereby materially reduced the damage to private connections.

In this repair work, 350 driven ferrules were replaced by corporation cocks to date, the tapping machines having been of marked assistance.

It is remarkable that some large cities have been slow in utilizing inventions such as the tapping machine, which has been in constant use by constructing engineers for a quarter of a century or more.

While not strictly a feature of reconstruction, some facts concerning efforts to correct the pollution of the stream from which York draws its water-supply may be of interest.

Early in 1898 the presence of typhoid fever in York demanded attention, and an investigation revealed the fact that some 20 miles up the stream there had been cases of typhoid fever, and that the ejecta of patients was so placed as to reach the stream without proper disinfection, giving reasons for tracing the York cases to the locality named. Bacteriologic examinations were promptly made, but gave no positive evidence of the dreaded germs, for, as is often the case, the interval between their reception and the development of the disease

was sufficient to permit of the supposed objectionable bacilli passing from the water.

A physical examination, however, was more fruitful, and numerous sources of pollution were discovered.

We made a thorough reconnaissance of the drainage basin, prepared a map, and upon it located observed sources of pollution, using the camera as a valuable adjunct. Assistants were delegated to note these and to personally require the abatement of the nuisances.

In a large number of instances the requests of agents of the York Water Company were sufficient to secure the abatement of nuisances. Others were only remedied after a magistrate had bound over the offender to appear at court, and other cases required the finding of true bills by the Grand Jury. In but one instance is there apparent intention to contest the matter in the courts.

In view of the claim that existing laws of Pennsylvania are insufficient to reduce stream pollution, the success which has so far attended the efforts of the York Water Company would indicate the old adage "where there is a will there is a way" as applicable. This should not be interpreted as opposing any effort to secure better legislation, but as an expression favoring the exhaustion of the provisions of existing statutes as the best demonstration of the direction which additional legislation should follow.

Section 6 of the Act of June, 1885, gives the State Board of Health authority to abate nuisances where there is no local health board or where the regulations of such board are *inoperative*. The word inoperative seems to cover inactivity as well as inability.

A penalty, including a fine of $100, may be enforced.

The York Water Company appealed to the State Board of Health, and, securing its cooperation, assumed the expenses which the inspection and prosecutions demanded, with the following result:

Number of formal notices to abate nuisances served on those who controlled them,	103
Number of abuses satisfactorily abated upon such notice,	81
Number of nuisances partially abated, with assurance of increased care,	10
Number of arrests made,	12
	103
Number of true bills returned by the Grand Jury against those who maintained nuisances,	11

THE ENGINEERS' CLUB OF PHILADELPHIA

1122 Girard Street

OFFICERS FOR 1899

President

FRANCIS SCHUMANN

Vice-Presidents

Term Expires January, 1900
W. C. L. EGLIN

Term Expires January, 1901
HENRY LEFFMANN

Directors

Term Expires January, 1900

C. H. OTT — EDWIN F. SMITH

RICHARD L. HUMPHREY

Term Expires January, 1901

MINFORD LEVIS — HARRISON SOUDER

W. PENN EVANS

Secretary

L. F. RONDINELLA

Treasurer

GEORGE T. GWILLIAM

STANDING COMMITTEES OF BOARD OF DIRECTORS

Finance—W. C. L. Eglin, Henry Leffmann, Minford Levis.
Membership—Edwin F. Smith, W. Penn Evans, C. H. Ott.
Publication—Henry Leffmann, Richard L. Humphrey, C. H. Ott.
Library—Richard L. Humphrey, Minford Levis, Harrison Souder.
Information—Harrison Souder, W. Penn Evans, W. C. L. Eglin.
House—Minford Levis, Richard L. Humphrey, Harrison Souder.

SPECIAL COMMITTEES OF THE CLUB

Relations of the Engineering Profession to the Public—John Birkinbine, *Chairman.*
New Club House—W. Copeland Furber, *Chairman.*

MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, January 7, 1899.—The President in the chair. Seventy-nine members and visitors present.

Mr. John Birkinbine read a paper on the "Reconstruction of the York, Pa., Water-supply." Also a paper on a proposed "New Power Improvement on the Niagara River."

These communications were discussed by Messrs. Schermerhorn, Richards, Easby, Christie, and others.

The tellers announced the following elections: Messrs. J. A. Lafore, P. J. A. Maignen, and Geo. Tatnall to active membership, and Mr. J. B. Strong to junior membership.

ANNUAL MEETING, January 21, 1899.—The President in the chair. One hundred and six members and visitors present.

The retiring President read his address, entitled "A Few Phases in the Rise and Development of the Science of Mechanics."

The tellers announced the election of the following officers for the year 1899:

President, Francis Schumann.

Vice-President, Henry Leffmann.

Secretary, L. F. Rondinella.

Treasurer, Geo. T. Gwilliam.

Directors, Wm. Penn Evans, Minford Levis, and Harrison Souder.

Mr. Carl Hering exhibited specimens of tubes and wires obtained in the laboratory of the late John W. Keely.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, January 7, 1899.—Present: The President, the Vice-Presidents, Directors Schumann, Levis, Hartley, Humphrey, Ott, and Smith, the Secretary, and the Treasurer.

Resignations of active membership were presented and accepted from Messrs. George Burnham, Jr., Howard Constable, Frank R. Ford, S. A. Jellett, Coleman Sellers, William Sellers, Norman L. Stamm, Geo. C. Thayer, and Russell Thayer, to take effect December 31, 1898.

The Treasurer reported the names and indebtedness of nine members dropped on December 31st for non-payment of dues, in accordance with the provision of Art. VII, Sec. 2, of the By-Laws.

The Treasurer's Report for December showed:

Balance, November 30, 1898	$835.48	
December receipts	1185.80	
		$2021.28
December Disbursements		1146.27
Balance, December 31, 1898		$875.01

The Treasurer presented his annual report for the fiscal year 1898, which was accepted and ordered to be published with the report of the Board.

The annual report of the Board of Directors was prepared for publication.

The Membership Committee recommended that Mr. Robert D. Coombs, Jr., be transferred from junior to active membership, in addition to Messrs. A. H. Holcombe, H. J. Lamborn, and Irving B. Smith, whose transfers were approved by the Board at its last meeting; and the Committee reported that, in accordance with the Board's instructions, it had learned that Messrs. J. Ogden Hoffman and J. B. Bonner, both of the Carnegie Steel Company, desired to be transferred from associate to active membership, and recommended that Mr. J. W. Ridpath be transferred from associate to active membership upon his own application, as a mistake was made in classification at the time of election. The Committee's recommendations with regard to transfer of junior members to active membership were approved, and it was resolved that associate members recommended by the Membership Committee for transfer to active membership should be balloted upon by the Club.

REGULAR MEETING, January 21, 1899.—Present: The President, the Vice-Presidents, Directors Hartley, Levis, Humphrey, Schumann, Smith, and Ott, the Secretary, and the Treasurer.

Resignations of active membership were presented and accepted from Messrs. Wm. J. Hoyt and J. J. de Kinder, to date from January 1, 1899.

The Secretary was instructed to hereafter omit the announcement of lunch from the notice of meetings.

ORGANIZATION MEETING, January 28, 1899.—Present: The President, the Vice-Presidents, Directors Humphrey, Ott, Smith, Evans, Levis, and Souder, the Secretary, and the Treasurer.

Standing Committees for 1899 were announced as follows:

Finance: Wm. C. L. Eglin, Henry Leffmann, Minford Levis.

Publication: Henry Leffmann, R. L. Humphrey, C. H. Ott.

Library: R. L. Humphrey, Minford Levis, Harrison Souder.

Membership: Edwin F. Smith, Wm. Penn Evans, C. H. Ott.

Information: Harrison Souder, Wm. Penn Evans, Wm. C. L. Eglin.

House: Minford Levis, R. L. Humphrey, Harrison Souder.

The following committees for the fiscal year 1899 were appointed by the Board, the first named in each case being chairman:

Regular Tellers: H. V. B. Osbourn, Walter L. Webb, Harrison W. Latta.

Alternate Tellers: S. E. Fairchild, Jr., Geo. B. Taylor, Geo. N. Leiper (with Mr. R. G. Develin as a substitute in the event of any declination).

Auditors: James Christie, H. W. Spangler, W. P. Dallett.

On the Standing Committees "On the Relations of the Engineering Profession to the Public" and "On New Club-house" the President reappointed for 1899 the members who constituted these committees for 1898.

L. F. RONDINELLA,
Secretary.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

FOR THE FISCAL YEAR 1898

JANUARY 21, 1899.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-laws, the Board of Directors offers the following report of the affairs of the Club for the year ending December 31, 1898.

During the year eighteen regular meetings and one special meeting were held, at which the maximum attendance was 116 and the average about seventy. The special meeting was held as a substitute for the stated meeting which fell on January 1st and for which, by agreement, no business was provided. The attendance of this meeting was merely nominal and is omitted in the calculation of the average attendance given above.

Nine stated and five special meetings of the Board of Directors were held, at all of which a quorum was present. The business of the Board has been carried on satisfactorily during the entire year and the reports of the various committees, which are herewith appended will show that many important improvements have been made in the Club house and in the conduct of the Club affairs.

MEMBERSHIP COMMITTEE.

During the year, thirty-one active, six associate, and six junior members were elected; twenty-four active and one associate resigned, and nine active members were dropped from the rolls.

The record of death is as follows:

Leighton Lee, Active Member, died November 15, 1898.

The membership of the Club, on December 31, 1898, as compared with the previous year, was as follows:

	1897.			1898.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total.*
Honorary.....		1	1		1	1
Active	279	114	393	281	110	391
Associate	15	2	17	20	2	22
Junior	6	0	6	9	2	11
	300	117	417	310	115	425

INFORMATION COMMITTEE.

The Information Committee, during the past year, has made every effort to furnish papers which would be of interest to the various branches of engineering represented in the Club. On account of a number of authors being unable to present their papers on the dates fixed, the Committee was unable to publish a program in advance. It is expected that this will be accomplished for the next year.

The Committee will be glad to have suggestions for the topical discussions which are held twice a year, and to receive papers, particularly short ones, from members.

The following papers have been presented during the year:

JANUARY 8.—The Keely Motor. E. A. Scott.

JANUARY 15.—Annual Report of the Board of Directors. Address of Retiring President, Joseph T. Richards.

FEBRUARY 5.—Various Phases of the Road Question. Roy Stone.

FEBRUARY 19.—The Dome of the City-Hall Tower at Philadelphia. Francis Schumann.

MARCH 5.—The Inspection of Buildings. Benj. Franklin.

MARCH 19.—Topical Discussion—Modern High Explosives.

APRIL 2.—The Engineering Chemistry of Boiler-Waters. Henry Leffmann.

APRIL 16.—The Deep-Well Pumping Plant at Waukesha, Wis. J. W. Ledoux. A New Inertia Indicator. Wilfred Lewis.

MAY 7.—A Case of Jurisprudence in Land Surveying. A. E. Lehman. Exhibition of slides illustrating systems of mine timbering. John Birkinbine.

MAY 21.—The Diesel Motor. E. D. Meier.

JUNE 4.—Recent Developments in the Application of Storage Batteries. Joseph Appleton.

SEPTEMBER 17.—Topical Discussion—The Proper Proportions of Parts of Steam Engines.

OCTOBER 1.—The Dow Engine (Corliss Foundation) and the Chronometric Governor. Josiah Dow.

OCTOBER 15.—The Construction of the Pennsylvania Avenue Subway and Tunnel, Philadelphia. Geo. S. Webster. Movement of Water-mains. A. J. Fuller.

NOVEMBER 5.—Coal Handling Machinery. Charles Piez. Notes on Recent Progress in Electrical Engineering. Carl Hering.

NOVEMBER 19.—Engine and Boiler Testing. Henry W. Spangler.

DECEMBER 3.—Cement and Cement-testing Laboratories. R. W. Lesley.

PUBLICATION COMMITTEE.

The Publication Committee reports that during the year 1898 a more frequent issue of the Proceedings has been made than heretofore. Including the number printed at the close of December, six numbers have been issued, of which five have been assigned to Vol. XV. This volume is now closed and the index will form part of No. 5. The frequency of issue has permitted the publication of the papers more promptly then heretofore, and it is believed that this fact has been very acceptable to the members. The total number of pages in Vol. XV is 299, exclusive of title and index. Each number has been copyrighted. Many of the articles have been extensively copied and all have elicited interest from the engineering profession.

The Committee has not been able to obtain all papers promptly, and in a few cases has been unable to obtain matter in proper form for publication.

The typographical appearance of the Journal has been improved, and it may be added that the advertisements have been more extensive, and the revenue therefrom was much larger than for several years past.

FINANCE COMMITTEE.

	EXPENDITURES FOR 1897	ALLOTMENTS FOR 1898	EXPENDITURES FOR 1898	ESTIMATES FOR 1899
Salaries	$1,221 50	$1,600 00	$1,536 25	$1,600 00
Proceedings	651 28	900 00	1,409 68	1,000 00
House Expenses	1,445 65	1,500 00	1,496 33	1,500 00
Luncheons	696 00	700 00	687 00	700 00
Notices	329 66	350 00	261 12	
Secretary's Office	176 13	200 00	261 54	500 00
Treasurer's Office	67 00	80 00		
Library	37 94	150 00	149 93	150 00
Information Committee	44 64	100 00	26 24	50 00
Investment	.....	.....	500 00	500 00
House Improvements	156 59	300 00	243 82	250 00
Liabilities for 1897 paid	.....	.....	210 30	.....
Total Expenditures and Estimates.	$4,826 39	$5,880 00	$6,782 21	$6,250 00

LIBRARY COMMITTEE.

The Library Committee has given its attention to the binding of a large number of volumes of periodicals and transactions of various societies. During the past year 123 volumes have been bound and placed in the cases of the reading room and on the shelves of the library.

The subscription and exchange lists have been maintained and extended.

HOUSE COMMITTEE.

The House Committee, believing that a reading and writing room would be appreciated, endeavored, by furnishing the rear room of the lower floor, to accomplish this end. Book-cases, chairs, a large writing desk, clock, etc., have been purchased; also suitably engraved stationery for the personal use of the members. These conveniences have made the room very attractive, and it is gratifying to the Committee to note that the Club house is being so well patronized at all times.

At the beginning of the year a janitor and janitress were appointed. This has resulted in a decided improvement in the condition and care of the house.

Unintentionally, yet happily, the personnel of the House and Library Committees was the same. Their duties being closely allied, made it possible to work harmoniously and expeditiously.

The question of introducing steam heat and electric light has been carefully considered, but the installation of same is not deemed advisable at present, as the general arrangement of the house is such as to prevent and render inadvisable the expenditure of much money for improvements. It is for this reason that the Committee finds it impossible to remedy the present badly arranged method of serving luncheons.

The Committee was allowed at the beginning of the year for house expenses $1500.00; of this amount $1496.33 has been expended. Of the $300.00 allotted for house improvements, $243.82 has been used.

Respectfully submitted,

L. Y. SCHERMERHORN, *President.*

L. F. RONDINELLA, *Secretary.*

REPORT OF THE TREASURER FOR THE FISCAL YEAR 1898.

Receipts.

Initiation Fees (43)	$215 00	
1896 Dues	17 50	
1897 Dues	302 50	
1898 Dues	4,800 00	
1899 Dues	475 00	
		$5,810 00
Proceedings (Advertisements)	$1,019 00	
Proceedings (Sales)	162 62	
		1,181 62
Interest on Deposits		27 30
Interest on Investment		5 54
Keys		2 25
Total Receipts		7,026 71
Cash Balance, Dec. 31, 1897		630 51
		$7,657 22

Expenditures.

Salaries:		
Secretary	$240 00	
Treasurer	60 00	
Clerks	823 75	
Janitor	412 50	
		$1,536 25
House:		
Rent	$1,100 00	
Coal	92 50	
Gas	93 80	
Ice	22 25	
Repairs	12 80	
Supplies	108 74	
Telephone	66 24	
		1,496 33
Furniture and Fixtures		243 82
Office Expenses		261 54
Proceedings		1,619 98
Notices		261 12
Information Committee		26 24
Library		149 93
Luncheons		687 00
Investment, U. S. Bond		500 00
Total Disbursements		$6,782 21
CASH BALANCE, DEC. 31, 1898		**875 01**
		$7,657 22

GEO. T. GWILLIAM, *Treasurer.*

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, check-, and bank-books, and find them to correspond with the Treasurer's statement as submitted above.

[Signed] JAMES CHRISTIE,
W. P. DALLETT,
H. W. SPANGLER,
} *Auditors.*

before their eyes all the great body of facts of exactly the same nature as those upon which civilized man has built the modern structure of physical philosophy; but with the former the scientific method for the attainment of knowledge has not been at work and the laws of force and motion are unknown. "The scattered stones are there, but the builder's hand is wanting." Even a high degree of intelligence may exist and yet with it be found a perfect barrenness of scientific attainment. Not until the human mind was led to a constant and careful reference of theory to observation and experiment did the evolution of physical philosophy become possible.

Living under the light and resources of the close of the nineteenth century, it is not easy to place ourselves in the mental attitude of those who lived during the ages in which all the scientific knowledge we now possess was unknown. We have been so accustomed throughout our lives to deal with cause and effect from the standpoint of the vast knowledge which we have inherited from the near past that it is difficult for us to realize a time when the phenomena of nature were only recognized so far as they applied to the rude wants of mankind; or if made the subject of speculative thought, were reasoned upon without due reference of theory to fact.

That department of science which treats of space, force, and motion has no less an embryology than science which deals with physical life. And as physiologists find that the real nature of existing organs can only be determined by tracing their evolution through fossil genera up to their highest present development, so a study of the embryology of the science of mechanics may lead us to a better conception of its existing organization. The genesis and development of this department of science, with which as engineers and physicists we so largely deal, is of such interest that I have chosen a few phases of it for presentation to you to-night.

Mankind began by discovering *a* relation, and ended by discovering *the* relation. The first achievement foretold the kind of phenomenon which would occur: the last foretold not only the kind, but the amount. To determine the amount, measures became necessary and standards of measurement for space, weight, and time were evolved. The reduction to practice of the comparison of things by measurement marked one of the great epochs of human advancement, for without it all development would have been impossible and the human race would,

therefore, have remained in a condition of savagery. That these standards of measurement were developed during the crude condition of the race is evidenced by the fact that our present measurements of space and weight had their origin in organic substances, such as the arm, hand, finger, and grains of wheat, corn, and barley, while those of time are derived from the periodic recurrence of events of nature.

Herbert Spencer calls attention to the fact that for those phenomena for which we have found no measures except our sensations, we have no sciences. We have no measures for tastes or smell and, therefore, no sciences of them. Before the establishment of measures, man's exact knowledge of weight and force was as unreduced as our present knowledge of tastes and smells. Before measures of time were invented, through the use of the hour-glass, the sun-dial, or the clepsydra, the duration of phenomena could be estimated with no greater accuracy than we can now estimate the degrees of hardness with the fingers. Until the thermometer was devised, man's judgment respecting relative amounts of heat was as vague as our present judgment in relation to amounts of sound. Without measures of comparison, more or less exact, only the rudest comparisons, only the most marked differences, could be detected; and as a result laws dependent upon exact measurements could not be surmised, much less determined. In passing, it may be conjectured with great plausibility of truth that the impulses of mankind toward religious and mercenary ends were powerful factors in establishing standards of measurement. To fix religious feasts, to measure land, and to weigh articles of barter were the practical questions out of which subsequently arose astronomy, geometry, and mechanics. The demand for better methods of meeting personal wants, or, in other words, human selfishness, was the incentive which pushed our race toward civilization.

Physical astronomy is so ancient that we can not ascend to a period when it did not exist. The assumed close relation between the stars and human destiny; the establishment of the year and its divisions; the fixing of religious feasts—all rendered necessary the study of the heavens by the priests; but in this study the scientific habit and element were entirely lacking, and to that extent hindered, rather than advanced, the development of the exact sciences.

Arithmetic and geometry were developed among the ancients to a marked degree, but their application to the demonstration of the

simplest fundamental truth of mechanics had not been conceived, since at that time the most elementary principle of the science of mechanics had not been guessed, much less discovered.

Between that epoch in human history when measures of space, time, and weight became fairly established, and the application of these measures to the simplest principle of mechanics, a long interval elapsed. There is no evidence to justify the assumption that the human mind, prior to about 250 B. C., in any of the many centers of civilization, had established, outside of observation, a single fundamental law of mechanics. This period in which Archimedes lived witnessed the birth of mechanics as a science; but it was only a birth, for as a science it remained literally undeveloped, with hardly a suggestion of growth, for over eighteen hundred years, or until about the end of the middle ages.

Before entering specifically upon the character and extent of the Greek genesis of mechanics, permit me to turn aside for a moment to consider an interesting question that probably arises in your minds. If the fundamental laws of the science of mechanics were but faintly conceived in the third century before the Christian era, and remained undeveloped until nearly the close of the sixteenth century, how was it possible that those wonderful works of constructive art could have been created between the most ancient times and the end of the middle ages?

If the colossal structures of ancient Egypt, Assyria, and Greece prove that mechanics then existed as a science, mechanics must have also existed as a science among the builders of the Cyclopean walls of Greece, or at Stonehenge, and elsewhere in the prehistoric world, when such masses were piled on one another as could not have been moved and raised into position without considerable skill. "The action of every man who raises and balances weights, or walks along a pole, takes for granted the laws of equilibrium; and even animals constantly avail themselves of such principles. Are these, then, acquainted with mechanics as a science? Again, if actions which are performed by taking advantage of mechanical principles prove a knowledge of the science of mechanics, they must also be allowed to prove a knowledge of the science of geometry when they act upon geometric properties. But the most familiar actions of men and animals proceed upon geometric truths; even asses know that the two sides of

a triangle are greater than the third, but they have not therefore a knowledge of geometry." And in like manner among men the practical assumption of a principle does not imply a speculative knowledge of it. We see these principles daily exemplified in the work of the laborer with his tools and appliances.

The wonderful structures of the world from the earliest times down to the close of the middle ages were the work of art and not of science. "Art is the parent, not the progeny of science." The admirable cathedrals were built by art, and not by science; but we find in the best work of the architects of all ages that the true idea of mechanical pressure intuitively existed among them more distinctly than among men in general, although it was not developed in a scientific form. We know that the cathedrals of Salisbury, Amiens, and Cologne preceded the earliest mechanical treatises of Stevinus by more than three hundred years; they were the works of artists and not of mechanicians. The slight insight into the science of mechanics which had been gained by the Greeks was all unknown to the great builders of the middle ages, just as those principles were unknown to the builders of ancient Egypt, Assyria, and Greece; and yet they created not only enduring works, but such as command our admiration and wonder to this day, through the magnitude and difficulty of the constructive problems involved. The constructive inventions of earlier times were devised by practical builders of large experience; and though the science of mechanics could afterward justify, it did not suggest them. They are not the result, much less the application of theory, but only its exemplification. To pursue this interesting question further would lead us too far away from the subject we had entered upon, and I therefore return to the birth of mechanical science among the Greeks.

The doctrines enunciated by Aristotle, in the century before Archimedes, were reaffirmed by his followers down to the time of Galileo, and the philosophic minds of the world had grown accustomed to regard Aristotle's teachings as so nearly inspired that it rarely occurred to any later philosopher to doubt their truth. He taught that levity is a positive quality of matter as well as gravity; that weight was the cause of motion in falling bodies; that the space through which falling bodies would pass in a given time was exactly proportionate to their weights; and the denial of this law nearly cost Galileo his life.

It was considered by Aristotle a difficult problem to explain why a stone thrown from the hand moves for a time and then stops. In reasoning about the problem he said: "If the hand causes the stone to move, how can the stone continue to move after it has left the hand? If the hand is not the cause of the stone's motion, why does it not continue to move forever?" His answer to the difficulties presented was as follows: "There is a motion communicated to the air, the successive parts of which urge the stone forward, and the air thus continues to act for some time after it has been acted upon; the motion ceasing when the stone comes to a particle of air which can not act after it has been acted upon." Under this theory the forward motion of the stone ceased suddenly, after which it fell vertically to the ground. Such a doctrine of force and motion was held as satisfactory for over eighteen hundred years. In 1550 a celebrated mathematician stated that the path of a cannon ball was a straight line for osme distance after leaving the cannon's mouth; afterward an arc of a circle until the propulsive force of the cannon ceased, when the remainder of the trajectory was a vertical line.

The problem of the lever attracted Aristotle's attention, and he taught his disciples that the reason why a force acting at a greater distance from the fulcrum moves a weight more easily is because the force describes a greater circle; that when a body at the end of the lever is put in motion, it may be considered as having two motions—one in the direction of the tangent, the other in the direction of the radius. The former, he says, is *according to nature;* the latter, *contrary to nature:* that in the smaller circle the motion contrary to nature is much greater than in the larger circle; therefore the motion according to nature will be easier than the motion contrary to nature. Aristotle's answer to the question, Why does a small wedge raise great weights? was, Because the wedge is composed of two opposite levers. Why can a stone be thrown farther with a sling than with the hand? Because when the stone is thrown from the hand, it moves from rest; but when thrown from a sling, it is in motion. These are samples of Aristotle's physics. They were the best the world had known to that date, and they were considered so satisfactory for nearly two thousand years that they caused Galileo and his contemporaries no small trouble to displace.

Aristotle and his followers collected a host of facts, but they derived

no general law from the facts, and, consequently, when his physics attempted to explain the facts, it had no principles which were of value or avail. Mechanics and hydrostatics are founded to-day upon phenomena with which Aristotle was as familiar as we are. The defect in his philosophy was neither in the depreciation of the value of facts, nor in the neglect of their use, but "the defect was that though he was in possession of both facts and ideas, the ideas were not distinct and appropriate to the facts."

The indistinctness of thought on mechanical subjects belonging to this period is well illustrated by the then established belief among intelligent men in the marvelous mechanical power of a little fish, the echeneis, which was said to be able to stop a great ship by simply adhering to it. Of this creature a writer said: "What is more violent than the sea and winds? What is a greater work of man than a ship? Yet a little fish, the echeneis, can hold back these when they all strain the same way. The winds may blow, the waves rage, but this little creature controls their fury and stops a ship when chains and anchors would not hold it; and this it does not by hard labor, but merely by adhering to the ship." It was said to have frequently interfered in naval battles, to the great disadvantage of the ship to which it adhered. In one case, where the matter is reported to have been carefully examined, it was found attached to the rudder, and had successfully held back 400 rowers. It was particularly described as being about eighteen inches long, in appearance like a slug, and to have no power when taken out of the water.

This was the general condition of the science of mechanics when Archimedes, about one hundred years later, or about 250 B. C., first correctly apprehending weight and force, demonstrated upon correct principles the general proposition that "equal weights suspended from a lever with equal arms would remain in equilibrium; that a lever with unequal arms was in equilibrium when one weight multiplied by its arm, was equal to the other weight into its arm"; that "in every heavy body there is a definite point called a *center of gravity*, in which point we may suppose the weight of the body collected."

The practical proof of this principle of the lever had been obvious and universally recognized by mankind from the remotest ages, but the human mind had never before reduced it to a demonstration, so that its truth, like a geometric demonstration, became evident inde-

pendent of experience, and was thereby seen to be a rule to which experience must conform. Aristotle had failed because he sought for the solution in vague and loose notions about natural and unnatural motion; though in a mode of speculation that so bewitched the human mind for nearly two thousand years as to hinder until the sixteenth century the prosecution of the true scientific method of Archimedes in the study of the science of mechanics.

Archimedes not only established the foundation of the statics of solid bodies by this demonstration of the principles of the lever, but he rendered an equal service to the science of hydrostatics by his discovery that "fluids press equally in all directions, and from this solved the problem of floating bodies—namely, that they are in equilibrium when the upward and downward pressures are equal." According to Plutarch, his discoveries in hydrostatics led him to detect the dishonest introduction of alloy into King Hiero's crown, by comparing its fluid displacement with the displacement of an amount of pure gold equal to the weight of the crown.

The demonstration by Archimedes of the problem of fluid equilibrium was the more remarkable since its truth was less self-evident than the principle of the lever. The expansion of the subject remained unpursued until the revival of science in modern times, and when again put forward the main proposition was so far from being obvious that it was then, and is to this day, known as the *hydrostatic paradox.*

After these principles of the lever and of fluid equilibrium had been clearly demonstrated by Archimedes 250 B. C., his doctrines practically slept for over eighteen hundred years, or until revived by the school of philosophers of the latter half of the sixteenth century. Nor was this the only loss, for the ground which Archimedes had so grandly won was not even steadily maintained. Subsequent investigators, not appreciating the force and truth of his demonstrations, constantly tended to revert to the erroneous mechanical notions of Aristotle, from which no valuable results could be derived. Whewell says: "Archimedes' followers had not clearly apprehended the idea on which his reasoning altogether depended. The clouds which he had for a moment cloven in his advance closed after him, and the former dimness and confusion settled again on the land." Beyond the abstract value of his discoveries, science was his larger debtor

through the value of his method in dealing with scientific speculation upon the basis of seeking facts, and then applying to them distinct ideas appropriate to the facts.

A proper conception of Archimedes' discoveries and methods of reasoning should have led philosophers much earlier than it did to an expansion of the principles which he had demonstrated; but through the persistence of the doctrines and methods of reasoning of Aristotle, joined with the indistinctness of ideas in mechanics during the dark and middle ages, no development of Archimedes' ideas occurred. During the dark ages men's minds were asleep, and during the middle ages mysticism held almost supreme sway. Instead of referring the events of the external world to sensible cause and effect, they were assigned to spiritual and supernatural causes, to past or future events in the moral world, and to demonology. Physical science became magic, chemistry became alchemy, astronomy became astrology, and mathematics the spiritual relations of numbers. The common sense of mankind teaches that theory is to be calmly tried by its consequences and its accordance with fact; during the larger part of the middle ages this truism was forgotten, and not infrequently facts were tried and condemned for their non-conformity with theory. If men thought, it was to repeat the thoughts of Aristotle and his followers as though the master had been inspired. No degrees could be taken in the universities without a large knowledge by the candidate of Aristotle's teachings, or without full approval of his doctrines; as late as 1452 this was the established rule of the University of Paris.

We pass over the interval of more than eighteen hundred years between Archimedes and the middle of the sixteenth century without finding a single advance in the science of mechanics or of hydrostatics. Between 1545 and 1585, Cardan, Ubaldi, Benedette, and Varro attempted to solve the principle of the inclined plane; but, guided more by the vagaries of Aristotle than the suggestions of Archimedes, they failed. In 1586 Simon Stevinus, of Bruges, Flanders, published his "Principles of Equilibrium," and also the "Principles of Statics and Hydrostatics," in which be demonstrated for the first time the principle of the inclined plane: the composition of static forces, or, as he expressed it, "three forces which act upon a point are in equilibrium when they are parallel and proportional to the three sides of any

plane triangle." He correctly applied his principles of equilibrium to cordage, pulleys, and funicular polygons; clearly distinguished between stable and unstable equilibrium; and established the difference between static and dynamic problems.

When the true principle of the inclined plane had been established, the laws of equilibrium for all the mechanical powers were a consequence of this discovery, and that of the principle of the lever already demonstrated by Archimedes; for it was easy to see that the wedge and screw involved only the principle of the inclined plane, and the pulley, wheel, and axle that of the lever.

In the field of hydrostatics, Stevinus demonstrated the hydrostatic paradox and gave the measure of pressure on any part of the side of a vessel filled with water. Whewell says of Stevinus that, "upon his foundations, and without additional support, the mathematical doctrines of statics might have been carried to the highest pitch of perfection they have yet developed. The formation of the science was finished; the mathematical development and exposition of it were alone open to extension and change." Stevinus was a Dutch engineer in the service of Prince Maurice of Orange, and in charge of the dikes of Holland.

The distinction, at this time, in men's minds between impact, momentum, force, and weight was very confused. An eminent philosopher of this period expresses his perplexity over the comparison of the forces of bodies at rest and in motion thus: "If the force of a body depends on its velocity, how is it that a body at rest has any force at all? and how can it resist the slightest effort, or exert any pressure?" He solved the difficulty to his satisfaction by venturing the conjecture that bodies at rest probably have an unseen motion, which results in producing force, and, therefore, pressure or weight. Unwarranted as we know such reasoning and conclusions to be, a brief review of the case will help us to a better conception of the manner in which motion, weight, and force were regarded at that time.

The most obvious manifestations of force were those derived from heavy bodies in motion. The moving arrow or stone, the falling sword or hammer, or any other moving body, when impressed upon objects at rest, gave most obvious indications of force and pressure, and a weight held in the hands conveyed to the mind a not dissimilar impression of force and pressure. The attraction of gravitation had not been even guessed as the cause of weight; therefore observers were

led to one of two conclusions—viz., that weight was either an inherent property of matter, or that it was the result of motion, and, if no motion was visible, it must be imagined as existing in some occult form.

The advance made in mechanics from the time of Archimedes to nearly the close of the sixteenth century had been toward the establishment of a science of equilibrium, while the science of motion had not been entered upon. To Galileo the honor belongs of first clearly perceiving and demonstrating a number of the principles of motion. In 1590, from the leaning tower of Pisa, he gave ocular demonstration of the falseness of the dictum of Aristotle, that heavy bodies fall with velocities proportional to their weights, and demolished with unanswerable logic maxims two thousand years old which assigned elemental weight and levity as properties of bodies. Galileo enunciated the principle of uniformly accelerated velocities; demonstrated that motion is the result of force, instantaneous or continuous; that weight is the result of a continuous force attracting the body toward the center of the earth; that in a vacuum all bodies fall with equal velocities; that when another force is impressed upon a body in motion, the additional force is compounded with the force which the body previously had; and established the theory of "virtual velocities," which Lagrange, in the next century, applied as the basis of the whole of rational mechanics. Galileo also entered upon the subject of the strength of materials, and published, in 1633, his solution of the problems of the strength of a beam fixed at one end and uniformly loaded; deriving the law that the strength of rectangular beams varied as their breadth and as the square of their depth; he also discovered that hollow tubes offer greater resistance to flexure than solid rods of the same length and quantity of material. Omitting any mention of Galileo's vast service to astronomy, allusion might be made to his discovery of the isochronism of the pendulum, the invention of the thermometer, and the development of the telescope.

Galileo thought quite clearly upon the subject of impact, but encountered difficulties which seemed insurmountable, for he said: "The force of percussion is infinite, for there is no resistance, however great, which can not be removed by the force of percussion, however small." This was upon the assumption that motion was instantaneously arrested; to remove the difficulty, he surmises that the resistance to

percussion possibly occupies some portion of time. This suggestion was really a great advance toward the solution of the third law of motion.

The interdependence of motion and force was not formulated by Galileo into definite laws, but his writings constantly suggest those laws, while his solution of dynamic problems involves their recognition. The opinion has been ventured that, without the mechanical conception of the dependence of motion upon force, which Galileo familiarized to men's minds, the problem might have remained a sealed book even to the intelligence of Newton.

The distinct mechanical apprehension of force is a modern conception. Archimedes discovered the elements of the theory of pressures upon bodies at rest, but it was not until the seventeenth century, by the labors of mathematicians from Galileo to Newton, that the general mode in which bodies move became sufficiently understood to give a perfectly definite meaning to the word "force"; in fact, the development of the idea has not yet ceased.

Copernicus, Tycho Brahe, and Kepler had preceded Galileo, and bequeathed to the world a wealth of suggestions relating to descriptive astronomy; but their speculations did not enter the field of physical astronomy, and they added nothing to the science of mechanics as previously developed by Archimedes and Stevinus. It was left for Galileo to take up the science, and, through the establishment of many of its important laws, to open the way for the rapid advance which followed. The evidence on which he had founded the principles of motion was their simplicity, and the agreement between their consequences and the facts they were intended to explain. The wide field which he opened immediately commanded the attention and labors of a host of workers, who might aptly be designated the School of Galileo.

Galileo had recognized that the air had weight, but he had failed to perceive why water refuses to rise above thirty-three feet in a closed tube, and could suggest no better solution than the answer of Aristotle, "that nature abhors a vacuum." In 1643 Torricelli, a pupil of Galileo, substituted mercury for water in the experiment; and finding that the suspended column of mercury was shorter than that of water in proportion to its greater specific gravity, he concluded that both columns were sustained by atmospheric pressure, and that

the weight of the superimposed column of air was equal to that of the suspended column of water or mercury. He immediately constructed the siphon-barometer, but its practical value was not generally recognized until 1647, when, through Pascal, the measurement of the height of a mountain was made by its use. The importance of this discovery to physics, and to a knowledge of the external world, is obvious.

Torricelli, in 1643, also demonstrated the theorem that a fluid issues from a small orifice with the same theoretic velocity which it would acquire in falling through a depth equal to the distance between the surface of the fluid and the center of the orifice; and that the velocity of the efflux of fluids from an orifice varies as the square root of the head, allowance being made for friction and the resistance of the air.

In 1656 Huyghens applied Galileo's discovered property of the isochronism of the pendulum to the regulation of the movements of clocks, producing for the first time the means for exactly measuring time. (Clocks before his invention were provided with a vibrating balance, incapable of exact regulation.) Galileo had, with considerable clearness, speculated upon the impact of bodies, but left the problem unsolved. About 1669 Huyghens transmitted a paper to the Royal Society of England in which he enunciated the principle that in impact the momentum in the striking body is as much reduced as it is increased in the body struck. Newton subsequently expressed this law by the statement that action and reaction are equal, and in opposite directions. In 1673 Huyghens solved the celebrated problem of the "center of oscillation," and determined, through a series of pendulum experiments, the acceleration of gravity, or the value of g, at the surface of the earth. He also demonstrated the composition of forces in circular motion, explained centrifugal force, and compared the force of gravity with this force in revolving bodies. From his views on centrifugal force he deduced the oblate form of the earth, but estimated its compression at about one-half its actual amount.

By the middle of the seventeenth century the philosophic mind had thrown off the bondage of the middle ages, and observation, theory, and speculation had awakened an intelligent interest in, and investigation of, the phenomena and laws of the external world.

The pupils of Galileo, moving from the point of departure established by their master, had made substantial progress toward the solution of many of the problems of mechanics. Philosophers, from Galileo to Newton, had accepted the conclusion that weight was the result of the attraction of the earth; that this attraction was the cause of bodies falling to the earth; and that it operated on falling bodies as a uniformly accelerating force. They gave to this force the name of gravity; but before the era of Newton attraction of gravitation was not conceived of as a property of all matter, but rather as a positive force emanating from the earth, which attracted bodies toward itself.

As early as 1666 Newton had been led to inquire whether the earth's attraction extended to the moon; and, if so, whether its attraction at that distance would be of the exact magnitude to retain the moon in its orbit. Assuming that the mean distance of the moon was equal to sixty semi-diameters of the earth, he found that the moon was deflected from the tangent through a space of thirteen Paris, or nearly fourteen English, feet in each minute. Knowing the distance through which a body would fall in one second at the earth's surface, by assuming that the earth's attraction diminished in the ratio of the inverse square of the distance from the center, he found that the earth's attraction at the distance of the moon would draw a body through $15\frac{1}{12}$ Paris, or sixteen English, feet in a minute. This apparent failure between theory and fact caused Newton to dismiss his conjecture as inaccurate. His calculations had been based upon the assumed diameter of the earth derived from the then accepted estimate that the length of a degree of latitude was sixty miles. In 1672 Picard had redetermined the length of a degree of latitude, and found it 69.1 statute miles; thereby giving the earth greater magnitude than had been ascribed to it by Newton in his earlier calculations, and therefore increasing the previously estimated distance between the earth and the moon. On the basis of this new determination Newton recalculated, in 1682, the problem of the moon's motion around the earth, and found that the moon was deflected from its tangent sixteen feet in each minute, and that this amount was equal to the distance which a body would fall in one minute, under the earth's attraction, at the distance of the moon. These results so exactly agreed with his theory that Newton now regarded his former conjectures as established—that

the earth's attraction extended to the moon, and retained it in its orbit around the earth.

His discovery was not that there was a force of gravitation, but his discovery was that this force is not confined to the limits of the earth. This discovery immediately opened to the mind of Newton the universe, and enabled him to pass from the particular case to the generalization that attraction of gravitation, instead of being simply terrestrial, was universal; and that any two masses in the universe attract each other with a force which varies according to the inverse squares of the distance.

The genius of Newton went to the stars for evidence and confirmation of the principles which before had been sought only in terrestrial phenomena. His discoveries identified celestial with terrestrial mechanics, and taught the world that the force which turned the plodding water-wheel was the same as that which wheels our planetary system around the sun.

Newton's "Principia," or "The Mathematical Principles of Natural Philosophy," was placed in the hands of the Royal Society of England in 1686, and published 1687. He therein stated the three laws of motion:

I. "Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state."

II. "Change of motion is proportional to force, and takes place in the straight line in which the force acts."

III. "To every action there is always an equal and contrary reaction; or the mutual actions of any two bodies are always equal and oppositely directed."

Galileo was acquainted with the first two of these laws, and seems to have formed some conception of the third in his speculations upon the impact of bodies; and later physicists, prior to Newton, were acquainted with the third law in a few of its many applications. But these laws as a system were first clearly enunciated by Newton, and extended in the "Principia" into the splendid demonstrations which he reared upon them. These problems deal mainly with the mechanics of solids, but they also consider the resistance of fluids to motion, and, somewhat, motion in fluids, or hydrodynamics.

The "Principia" is the foundation not only of modern astronomy,

but of the modern mechanics of solids and mathematical physics; and the wonderful scientific development which has been made of these subjects since the era of Newton is only the sequence of his doctrines of force and motion. To attempt to trace this later development would be impossible within the limits of time at my disposal.

To the time of Newton the subject of hydrodynamics had remained almost undeveloped; and the consideration given to this department of mechanics in the "Principia" was mainly confined to the theoretic velocity of a fluid issuing from an orifice, to the resistance which solid bodies encounter in moving in a fluid, and to the velocity of wave propagation. These problems were simply explorations into a wide domain, and left the science of hydrodynamics exceedingly incomplete. Since the time of Newton the labors of the Bernoulli brothers, Maclaurin, Lagrange, D'Alembert, Euler, Dubuat, Prony, Eytelwein, and others, brought the science down to the beginning of the present century.

In the mathematical consideration of the motion of fluids the theorist has the hypothesis of absolute relative mobility among the particles, combined with the laws of motion. These are conditions too vague and general to lead to satisfactory conclusions, since the assumptions of the mathematician do not probably here represent the real conditions. In the main, the theoretic investigation of motion in fluids is more complex and abstruse than motion in solids; and the solutions of the problems of the former are not so satisfactorily confirmed by the results of observation as are the latter. As a result, the development of the science of hydrodynamics is more incomplete than that of any other division of mechanics.

In this summary only the salient advances of mechanics are noted, and it is not intended to suggest that the science of mechanics was not indebted for its advancement to other names than those herein mentioned. The history of the science after the sixteenth century carries a noble roll of devotees who, by experiment, observation, and speculation, added here a line and there a precept toward the principles which Newton later built into the modern structure of mechanics.

In a sense, the science of mechanics which has been here traced is ideal, and without modification would be of small value to the engineer; it is pure or absolute mechanics—"absolute in the sense that its propositions are unqualified. It is concerned with statics and dynamics in

their pure forms; deals with forces and motions considered as free from all interferences resulting from friction, resistances of media, and special properties of matter. If it enunciates a law of motion, it recognizes nothing which modifies manifestation of it. If it formulates the properties of the lever, it treats of this, assuming it to be perfectly rigid and without thickness—an impossible lever. Its theory of the screw imagines the screw to be frictionless; and in treating of the wedge, absolute incompressibility is supposed. Thus its truths are never presented in experience, and the inferences to be drawn from them deviate very considerably from the results reached by experiment. Nevertheless, this system of ideal mechanics is indispensable for the guidance of practical or applied mechanics. The engineer has to deal with its propositions as true in full before he proceeds to qualify them by taking into account the natures of the materials he uses." In other words, through experiment, observation, and experience arbitrary constants must be determined, and introduced into the equations and resulting formulæ of pure mechanics, before such formulæ become a safe guide to the engineer. The determination of these constants is the real work of the modern investigator of the science of mechanics.

The origin of mechanics was the application of the principles of force and motion to the development of exceedingly simple machines; but in consequence of the vast career into which the principles of motion have been drawn by the splendid problems presented by modern mechanics, the simple origin of the science is almost forgotten. Just as geometry long ago outgrew the demands of land measurement, so the science of mechanics has gone far beyond the narrow limits which first circumscribed its simple machines.

In these last years of the nineteenth century, mankind is entering upon the grandest era of human progress and development that the world has ever seen; and none doubts that this future development will be almost unlimited, and that its results will be beyond conjecture. Of the factors which will contribute most potently to such an end, the mechanic arts and sciences will be the greatest; and as they have lifted the world from the darkness of superstition, so they will lead it into a light of which we dare not dream. The simple problem of Archimedes has led mankind to the discovery of the lever, fulcrum, and force wherewith to move the world.

NOTE.—In the above paper the statement will be noted that the builders of the great cathedrals, erected during the middle ages, were not conversant with the laws of the science of mechanics, and therefore these works were the result of artistic instinct and experience, rather than a definite knowledge of the laws of equilibrium, which were involved in the successful construction of the arches and supporting columns of these cathedrals. Abundant support for this inference is found in the writings of a large number of authors, and while I had then no reason to doubt the accuracy of the conclusion reached, it must be confessed that it was necessary to ascribe to these builders a larger measure of correct intuition than should properly be depended upon in engineering construction.

Since the paper was prepared for publication I have met with a statement by Mr. Gustav Lindenthal, the eminent engineer of the North River bridge at New York, to the effect that the cathedral builders of the middle ages employed a graphic method for determining the equilibrium of their arches and supporting columns, through the use of the "*Bauwage*," or building balance. This consisted of a flexible cord in the form of an inverted arch, passing over pulleys at either end; the cord being drawn into an equilibrium polygon by weights suspended at various points along the cord, each proportionate in position and amount to those which the arch would be required to carry at its various points; the whole system being held in equilibrium by weights attached to the vertical ends of the cord after passing over the pulleys at each end; these latter weights being also a measure of the horizontal force exercised by the system, or the horizontal thrust of the arch under consideration. By this method an equilibrium curve was obtained, the elements of which could easily be transferred to the arches, supporting columns, and buttresses to be erected.

This graphic method furnished these ancient builders with an easy and reliable method for determining the amount and direction of the pressures arising in their arches, as well as the amount of the horizontal thrust to be provided for. Of this method Mr. Lindenthal states that most German engineers are familiar with this history of the "Bauwage," and the use which the cathedral builders made of it. These builders were the so-called Master Builders, who formed a guild extending over Europe in the middle ages, with traditions, usages, and methods pertaining to the building art, the higher knowledge of which was reserved for only a few in each country.

The "Bauwage" was the funicular polygon, of which Simon Stevinus, in 1585, gave the demonstration of its mathematical correctness, it having been until then the product only of speculation and practical experiment. It was probably this prior and successful use of the "Bauwage" which led the engineer Stevinus to undertake its discussion and demonstration.

While this use of a graphic method, by the early builders prior to 1585, for determining the equilibrium of arches does not carry with it the assumption of a knowledge of the laws of statics involved in its principles, it does indicate that something more tangible than artistic instinct and intuition was guiding the old cathedral builders to the correct solution of their problems of construction.

L. Y. SCHERMERHORN.

THE PROBLEM OF WATER PURIFICATION FOR THE CITY OF PHILADELPHIA.

BY P. J. A. MAIGNEN.

Read February 4, 1899.

THE daily consumption of water in Philadelphia has gone on increasing by leaps and bounds, as is shown by the following table, published in the message of the Mayor of Philadelphia for the year 1897, and based upon the plunger displacements of the pumps:

YEAR.	POPULATION.	TOTAL.	PER CAPITA.
1860	565,529	30,398,198 gallons.	36 gallons.
1870	674,022	36,602,625 "	54 "
1880	847,170	57,898,719 "	68 "
1890	1,046,964	137,736,703 "	132 "
1897	1,200,000	257,500,000 "	215 "
1898		275,000,000 "	

On September 8th the consumption was 298,703,069 gallons, and the highest daily record of the year was on the 23d of October, with 340,000,000 gallons.

It is not for us to account for this extraordinary consumption of water, nor to inquire as to the desirability of seeking to diminish it. But it gives us an opportunity to state that in Europe systems of double supply are in favor. For instance, in Paris, one system delivers spring or filtered water, which is sold at about 24 cents per thousand gallons; another system distributes the raw river water at 12 cents a thousand gallons. The spring or filtered water is raised to a high point, so that it is always under sufficient pressure to reach the top of houses at all times. Some establishments use this water under pressure for motive power—in elevators, for instance. But to discourage the use of this water for industrial purposes the city of Paris has doubled its price, and sells it at 48 cents a thousand gallons when used for industrial purposes. In other cities in France the double system is recommended. The raw water may be kept at a low pres-

sure sufficient for such purposes as watering streets and gardens, flushing sewers, and supplying industrial establishments.

Considering that so many of the hydrants must be open at certain hours of the day, it is impossible that the water should rise in the high parts of the town when drawn from a single system. The pure water canalization, on the contrary, is not subject to such temporary extraordinary drafts, and can be maintained under high pressure at all times.

Philadelphia is so vast a city that a double system would be very costly, and it will be cheaper to filter all the water, even that wasted, than to tear open all the streets and place double mains. For new districts a double system might be used, so that the problem of filtration would be rendered considerably easier.

It is considered undesirable to increase the pumpage from the Schuylkill, as in periods of drought the pumps absorb the whole flow of the river, and sometimes draw on the reserve in the Fairmount pool, which is said to hold thirty days' supply. It is for this reason that in the last filtration project of Mr. Thompson, Director of Public Works, the quantity of water intended to be purified at the Spring Garden station for East Park reservoir is reduced from 150,000,000 to 100,000,000 gallons, and it is proposed to erect a new pumping station on the Delaware River.

Urgency.—We have to consider now the present supply, and the actual amount of money provided in the loan for the filtration of the city water-supply. What is to be done *now?* That is the question.

Any addition or improvement hereafter introduced will be welcome; but as something can be done now, let us deal with what is immediately attainable. Whatever filtration plant be erected now, will always be needed. If the water be taken from higher points on the rivers, or from still more remote mountain streams, the filters will have easier work, and require less frequent cleansings; but filters there must always be. Various proposals have been made to take the water for Philadelphia from the Delaware at a point above Trenton. We do not know how far this would improve matters, as Trenton does not seem to be quite satisfied with its water-supply. The sewers of Yardley, Lambertville, Phillipsburg, Easton, and several other small towns find their way into the Delaware, and are hardly more oxidized or otherwise rendered harmless when reaching Trenton than

the Trenton sewage itself at the time it reaches Philadelphia. Instead of spending the money in extra pipes, it would appear to us more reasonable to increase the power of the filters.

According to an ordinance recently prepared by Director Thompson, at the request of the Water Committee, the following are the quantities of water to be drawn from the Schuylkill:

East Park,	100,000,000 gallons.
Queen Lane,	70,000,000 "
Roxborough,	30,000,000 "
Belmont,	40,000,000 "

and from the Delaware River:

Frankford (Lardner's Point),	30,000,000 gallons.
Total,	270,000,000 "

The proposition for Frankford, or Lardner's Point, does not seem susceptible of execution, as it is now averred that Germantown and Frankford sewers send their deadly poison above and below this pumping station, and a proposition was introduced in Councils appropriating funds for the removal of this pumping station to a point at least three miles up the river, toward Torresdale. Allusion may be here made to the ideas of the Philadelphia Water Bureau concerning the intake in the Delaware. The pipes should be carried across the river far enough to avoid the flow of sewage which lingers mostly on the banks.

Another ordinance, also submitted by Director Thompson, asking for plans, specifications, and bids to erect a new pumping station and filter plant on the Delaware River, to deal with 150,000,000 gallons daily, has been introduced in Councils by the Water Committee.

Fairmount.—The old turbine station at Fairmount, which now pumps 40,000,000 gallons daily, is sometimes spoken of as of little use, on account of the number of weeks or months when there is not enough water in the river to run the turbines, or when they are thrown out of service by floods. One good word, however, ought to be said for this old friend of the Philadelphians: its running expenses are light, and when it works it is a great help to the whole system.

Reservoirs.—The reservoirs now in Philadelphia have a storage capacity of about 1,400,000,000 gallons of water, or about five days'

supply. It may be interesting to examine the use that can be made of them. Mr. Allen Hazen, in a paper read at the Franklin Institute on January 17, 1899, pointed out that the suspended impurities in the river waters should be classed under two heads: muddiness and turbidity; the former consisting of heavy matters that quickly deposit, and the latter caused by fine clay particles, which do not settle down appreciably, even if the water were at rest for days. According to Mr. George W. Fuller, who conducted the recent filtration experiments at Louisville, these fine particles of clay are smaller in size than the bacteria themselves. Mr. Hazen urged that reservoirs, unless they be large enough to allow the stoppage of the pumps during flood times, are not of very much use for clarifying purposes. The mud, sure enough, stops in the reservoirs (not all, as we can now see in our bath-tub), but the fine particles of clay remain suspended in the water; the water going out of the reservoir is still turbid when in the river itself it has gone back to a clear state.

The London reservoirs are large enough to allow of the stoppage of the pumps during flood, and so was it in Philadelphia years ago; but now the demand for water is so great, the pumping power so taxed, that if once stopped, the pumps could not make up for the lost time. In large reservoirs, moreover, the mud which accumulates is only removed at very long intervals; many hygienists in Europe object to them on that ground, and in London they are called "stinking pools."

If the turbidity be not removed by twenty-four or forty-eight hours' passage through the reservoirs, is it wise to increase the reservoir capacity for sedimentary purposes? Would it not be better to increase the pumping power and the filtering capacity? Our own opinion is that the existing Philadelphia reservoirs should be utilized partly for the removal of the coarser muddiness, and partly to hold a reserve of filtered water; filters being placed on the banks so as to take water from one and send it into the other. The reservoir or reservoirs should be cleansed at least once a year in set, good weather, and at that particular time the water might be sent direct from the river onto the filters.

Continuous Decantation.—The French engineers have solved this question by establishing in front of their filters continuous decanting compartments, wherein the muddiness is removed and the turbidity slightly diminished. They are cleaned every fortnight. The area

allotted to this purpose is equal to about one-fourth of the filtering area. Where reservoirs do not already exist, we do not think, as was said before, it is advantageous to build them for sedimentary purposes. They are estimated to cost about $4500 per 1,000,000 gallons daily capacity. It is acknowledged that to do anything at all in the removal of the turbidity they should be at least of two days' capacity, so that for 1,000,000 gallons daily flow through the sedimentary reservoir the cost of construction can be reckoned at $9000.

We propose to do this work of removal of muddiness and turbidity by means of continuous filtering decantation. It is well known that in large reservoirs the water that comes in does not readily mix with the other. A difference in temperature causes currents like that of the Gulf Stream, so that the incoming water does not mix readily with the greater body of water in the reservoir. This is very well illustrated at Washington. The reservoir known as Dalecarlia reservoir is most irregular in shape, as shown on the board. When the water that comes in is very muddy, the whole area is practically very muddy at the same time. In the distributing reservoir, on the contrary, which is regular in shape, the stream of dirty water can be seen pursuing its straight course, and not mixing with the surrounding clear water for a long time. In the continuous filtering decantation plant—the details of which we will give later—the muddiness is removed in a first compartment and the turbidity in two other compartments. The area occupied is not one-thirtieth of that of the sedimentary reservoirs. It does not cost, covered, $3000 per 1,000,000 gallons daily capacity, there is not six inches loss of head, and the flow is not impeded.

Hourly Consumption.—In Berlin the average hourly consumption from 6 P. M. to 6 A. M. is about 800,000 gallons, or nearly 10,000,000 gallons for the twelve hours. From 6 A. M. to 6 P. M. the average hourly consumption is about twice as much, or 21,000,000 gallons for the twelve hours. In Philadelphia the draft seems to be the same day and night. If the investigation now carried on by the Water Bureau prove this to be the case, small portions of the existing reservoirs will suffice for the filtered water, as the filter's hourly output is practically uniform day and night. If the variation is found to be anything like that of Berlin, a much larger part of the reservoirs must be utilized for the filtered water.

Water such as that of the Schuylkill and Delaware Rivers, particularly in times of flood, is, as every one knows, very difficult to purify, or even to clarify. We take it for granted that the muddiness has practically been removed by sedimentation or continuous decantation. In some cases it has been deemed desirable to add alum to the water, in order to coagulate the fine particles of clay by a sort of molecular attraction, so that the particles of suspended matter become big enough to be arrested by the sand.

Chemicals for coagulating cost much money; their introduction in the water constitutes an additional impurity, increasing hardness and corrosive action. I do not propose to employ chemicals of any description in dealing with the Philadelphia water-supply. This expensive means is replaced by a preliminary or primary filtration, which will considerably diminish the work that the sand filters will have to do.

Primary Filters.—It is well known that two principles are involved in filtration through granular beds—that of straining and that of adhesion. When the water percolates downward, the surface is quickly choked by the suspended matter. In upward filtration, on the contrary, the flow of water is not stopped until the voids in the whole of the mass of material are filled up. We therefore advocate upward filtration for our primary filters. The materials composing the beds are kept more or less loose by the effort of the water to rise through them, while in downward filtration the filtering materials are packed together closer and closer by the weight of the water. In our primary filters we attain a speed of 120,000,000 gallons a day.

The choice of materials for primary filters is very wide: gravel, coke, charcoal, etc., may be used, according to the special circumstances of each case. Knowing, as we do, the wonderful power of charcoal for purifying water, we propose to employ some of it in our primary filters, so as to help to oxidize the dissolved organic matter which is abundant in the Schuylkill and Delaware Rivers. Charcoal is an expensive material, but a small quantity does a great deal of good work.

The total thickness of material that we recommend for primary filters is about three feet. When the water of the river is clear, as it often occurs, it may be sent direct on the filter beds, and the primaries at that time may be entirely overhauled and dried, in reserve for freshets.

Sand Beds.—We will now proceed to describe our improved system

of sand filtration, and in doing so we will ask you to accompany us, step by step, in examining the motive of each of our improvements.

In examining a problem of this sort, or, indeed, of any other, we have to place before us three distinct propositions: Is it desirable? Is it possible? Is it practicable?

If we apply these propositions to the question of location for filters in Philadelphia, we will find that it is not desirable, neither possible nor practicable, to erect what are known as "old-fashioned," slow sand filters, exposed to the elements.

Land is most valuable within the city limits. Whether it belongs to the city or has to be purchased, it has a considerable intrinsic value; therefore it is desirable to find a way of doing the work on as small a space as possible. That this is possible and practicable you will see by our plans, wherein the land occupied is hardly one-tenth of what would be necessary for the erection of "old-fashioned" sand beds.

Is it desirable to cover filter beds in Philadelphia? To this we reply emphatically, Yes. If filter beds are not covered, the cost of maintenance will be most considerable, and very often unfiltered water will have to be sent into the mains.

In an article published in the "Engineering Record" of March 19, 1898, by Mr. Fowler, under the heading "Operation of Slow Sand Filters," at Poughkeepsie, N. Y., is a statement of some of the troubles attending open sand filters:

"One of the peculiar hindrances to the operation of the Poughkeepsie filters has been the growth of green, thread-like algæ on the surface of the sand. This sometimes appears in the latter part of May, and at other times not until September; some years it does not develop at all; it usually disappears with heavy frosts. It first appears in small, round patches on the surface of the sand, and continues to grow with greater or less rapidity, according to the condition and temperature of the water, until the entire surface is covered as with a blanket, and the passage of the water is entirely stopped. It has grown so rapidly as to stop filtration within seven days from the cleansing of the bed. Clear sunlight is essential for luxuriant growth, for it will not develop in the dark, and very little in the shadows of any object. Trouble was also caused by these algæ in the clear water basin, but since 1891, when a roof was built over it, there has been no trace of algæ."

The development of algæ is indeed a very noxious thing; a day

or two of rain or dark weather causes them to die, and they become rotten and give rise to marshy gases. Mr. Meehan, at the last meeting of Common Council, protested against the establishment of open sand beds in Philadelphia, on account of the stench which he said comes from the beds when they are emptied for cleaning.

The above-quoted article says, further: "The cold weather has been a source of trouble in the management of the plant. The first operation in winter cleaning is to remove the ice, which varies from ten to twenty inches in thickness; the maximum thickness of any cleaning was twenty-eight inches. The work is done by flooding the bed until the ice is level with the coping, when it is cut into pieces and hauled away; the engines are then shut down, and the bed drained. If the work is done during mild weather, and no frost occurs during the draining and cleaning of the bed, the filter will probably be in good order. More frequently, however, two or three inches of ice form while the bed is being drained, and this frozen mass must be removed instead of the ¼-inch or ½-inch layers which are taken off during warm weather. Sometimes the character of the river water changes so quickly that it is impossible to foresee the failure of the bed in time to remove the ice. In such cases an effort is made to clean the bed by lowering the ice on the sand, breaking it up, turning over the pieces, and cleaning underneath. This is very unsatisfactory, and undertaken only in emergencies; a sudden drop in temperature will sometimes even stop this operation before it is completed."

It may be said that the climate of Philadelphia is less severe than that of Poughkeepsie; but this is a matter in which it is not desirable to act on averages. There are surely times in Philadelphia when the cold is as severe as at Poughkeepsie, and it is not necessary for the thermometer to fall to ten or twelve degrees to occasion trouble to open filter beds. Anything below the freezing-point interferes, if not with the actual flow of the water, certainly with the removal of the sand, its washing, and its replacing on the bed.

We have tried to run an experimental plant in Philadelphia uncovered, but all the pipes and valves in which there was no current, or only a sluggish one, froze and burst. This might be avoided by incasing all the pipes, or by taking care that they will either be emptied or full of running water; but a greater trouble has attended this attempt. For nearly a fortnight the temperature has kept so low that we could neither remove the sand from the filter bed

nor wash it—the water freezing and the sand caking as soon as exposed. This leads us to the conclusion that not only the filter beds, but also the sand-washing arrangement must be inclosed. Much more could be said as to the inconvenience of open sand-filter beds, but we think this is enough for the present.

Our filtration plant in Cherbourg, our experimental plant in Paris, are covered, and we have never experienced for one single day or hour in the year the slightest inconvenience or trouble. The rain, snow, and heat interfere with open filters, but if they are covered and inclosed no trouble need be apprehended, and they can be attended to day and night in times of emergencies.

Thickness of Layers and Head of Water.—Great diversity of opinion exists as to what should be the thickness of the layers composing filter beds. At Poughkeepsie, for instance, the coarse materials under the sand are four feet thick, while an experimental sand filtration tank erected by Mr. Emil L. Nuebling and Mr. Allen Hazen at Reading, Pa., had only six inches of these coarse materials. In Germany the thickness of the gravel and stone layer varies from one foot to four feet; fine sand, from one foot to four feet. The head of water varies also from about two feet to six feet, and the total height of water, sand, and gravel varies from a little under four feet to over fifteen feet.

This disparity is very striking; the thicker the bed of sand, the greater the head of water necessary to overcome the resistance offered by the filtering medium. This coincides with our own observations. In filtration, high pressure is a mistake, first, on account of the expense due to the elevation of the water, and, second, because when a great body of water presses upon the filtering medium, it does one of two things, and often both: it packs and wedges the filtering media, or it opens up fissures and cracks, making by-ways wherever it finds the least resistance. When, on the contrary, the operation is carried on with little or no pressure, the granular materials are not packed, and cracks and fissures are less likely to occur.

The law of compensation seems to be true in filtration, as elsewhere. When working under pressure, the filtering materials must be finer and closer; if greater pressure is used, more resistance must be provided in order to obtain the same degree of efficiency. The speed, if quality is sought, is not materially increased by pressure. We prefer

the lesser head, on account of economy and security, and this is why our filter beds are only three feet three inches high, or, at most, four feet.

Walls.—It will be understood that the walls of filter beds ten or twelve feet high must be proportionately very thick and heavy, hence liable to cracks and fissures. Mr. Allen Hazen, in the lecture above mentioned, showed a drawing of the Albany filter beds, and indicated the measures he had taken against the water that might find its way into the filter through fissures in the retaining walls.

These walls, besides being costly, occupy a great deal of space. We prefer light masonry, or, better still, modern expanded metal, concrete, and cement structures based upon the Monier invention, and controlled in this city by our colleague, Mr. Merritt. The walls and floors of our filter tanks are made of this improved construction. A filtering plant on the "old-fashioned" sand bed system for 15,000,000 gallons maximum capacity a day would occupy about 7.11 acres of land; the filtering surface would amount to 6 acres, and as 1 filter at least out of the 6 would be under process of cleaning, this leaves 5 acres effective area.

Our filters, which are divided in 20 sections to the acre, would, if working at the rate of 3,000,000 gallons, occupy 5.75 acres. Built in 2 tiers, the area occupied would only be 2.87 acres.

Worked at the rate of 12,000,000 gallons per acre, the area is further reduced to 0.75 acres for plant equal to the filtration of 15,000,000 gallons.

For 300,000,000 gallons plant, the "old-fashioned" system would need about 215 acres; with our improvements less than 25 acres are sufficient.

Our primary filters occupy, in addition to the above, 10 per cent. more space, and when there is no reservoir for removing the muddiness, we also require 10 per cent. more land for the continuous filtering decantation. At East Park the ground between Thirty-third Street and the bank of the reservoir will be entirely occupied with a 3-tier filter house; if needed, it may be extended on the south side. At Roxborough we occupy a piece of land belonging to the city, close to the new reservoir, and build 2 tiers; there is room to increase the plant, if required, in the same line. For Belmont we propose a handsome filter house, with 2 tiers of filters erected over part of the new reservoir, which

will serve as sedimentation basin, and whence the water will be raised into the filters, from which it will flow by gravity into the old reservoir. At Queen Lane we also have on the south side of the reservoirs plenty of land for a filter house with 2 tiers of filters. If Frankford or Lardner's Point Pumping Station is retained, we can erect a filter plant on the ground adjoining the pumping station. There we would apply our continuous filtering decantation to the water flowing by gravity from the river; it would be raised by low-lift pumps into the primary filters at a higher level, whence it would flow into the sand filter beds, and by gravity to the high-service pumps.

Division of the Filtering Surface.—In the old-fashioned sand beds, which are generally made one acre in area, there is no way of ascertaining the state of the filtering surface when in use; and when taking off or putting on the sand, the work has to be done by hand labor. Planks are laid on the sand, and gangs of men work on them, using shovels, rakes, and wheelbarrows to take the sand over the bank. This, as can be understood, is not an economical way of doing the work. We divide our filtering areas, as said before, in small sections of about one-twentieth of an acre; our largest filter bed is about 16 feet in width and 130 feet in length, with two-foot pathways between two of these beds. The men can work thereon from the pathways, and remove the filtering membrane without going onto the sand, either by hand-rakes or by machinery such as is used for scraping the streets; the removal of the sand, returning of the same on the bed, will be done by mechanical conveyors, which will economize a great deal of labor.

Bacterial Efficiency.—The bacterial efficiency of sand filters is attributed to the formation of mud (or "Schmutzdecke") on the surface of the sand. This filtering membrane is held to be extremely fragile; hence it is that the engineers dare not allow the water to pass through sand beds at the rate at which it would pass if allowed to escape freely.

A sand bed composed of fine material would, if allowed to go without check, pass over 50,000,000 gallons of water an acre a day; but then, as will be understood, the surface would be quickly choked, the sand would be much packed, and many other troubles would attend such an operation. The lowest speed allowed in this country is 2,000,000 gallons per acre, and the maximum, 3,000,000 gallons per acre per day; but in Zurich and at Oporto 7,000,000, 10,-

000,000, and 13,000,000 are allowed to pass through. We must add, however, that it is said that in these places the water is fairly good before filtration. Another reason for the slow speed adopted in ordinary sand filters is that the cleansing operation takes from four to five days to perform: one day for emptying and drying the sand bed; one day, and sometimes more, particularly if the weather is rainy or snowy, for the removal of the mud or dirty surface of the sand; one day for replacing the sand on the bed; another day or two are also allowed for the new mud membrane to form on the surface, and during that time the filtered water is sent to waste. At 2,000,000 or 3,000,000 gallons per acre, the filter may go on, according to the season, a week, a fortnight, a month, and even six weeks without cleansing.

If these filters were allowed to go at 6,000,000, 8,000,000, or 12,000,000 gallons per day, the cleansing operation would have to be performed twice a week, every week, or every fortnight. Considering that it takes four or five days for the cleansing operation, it is obvious that there would be very little time for actual working.

The bacterial efficiency may be maintained with a high speed—as has been shown by Kummel, of Altona, and Bertschinger, of Zurich —if extraordinary care be bestowed on the operation, and the water fairly good.

Kummel's Experiment:

Filtration at the Rate of:	Bacteria Per Cubic Centimeter.
1,306,802 gallons,	11 to 97
2,613,600 "	5 to 79
5,227,200 "	5 to 72

Bertschinger's Experiment:

4,356,000 gallons,	20
5,227,200 "	31
8,712,000 "	22
16,262,400 "	15
21,489,600 "	18

The real weakness of sand beds lies, as we have said before, in the fragility of the mud deposit.

In the words of Mr. Henry Gill: "The chief cleansing action of sand filters takes place in the mud deposit on the surface of the

sand, and in the sand immediately at the surface. In this region the coating of deposit is soft, and, with its dense population, requires careful and tender treatment to avoid the squeezing out of the bacteria by undue pressure." This careful and tender treatment is very difficult to maintain. It is necessary to open the outlet valve little by little every day, so as to create an increased suction proportionate to the increased resistance of the thickening mud deposit. A mistake on the part of the attendant in opening the outlet valve too much may create cracks and fissures that foul the filtrate for several days afterward.

Improvements.—Our greatest improvement in sand filtration is the formation on the surface of the sand bed of an inorganic filtering membrane, the mode of application of which we will explain later on. With this non-fragile filtering membrane we can allow the speed to go up to 12,000,000 gallons without fear; it is our intention to stop filtering and start cleansing when the speed will have gone down to 9,000,000; by working at a lesser speed we could prolong the working periods or length of runs; in cases of emergency we can allow the filters to run full speed, even beyond the 12,000,000, without fear of breaking the filtering membrane.

One of the results of this inorganic membrane is that ninety-five per cent. of the bacteria and other suspended matter are retained by it, leaving to the sand below very little to do. Then when we have to clean after a week or fortnight's run, we let the water go down below the level of the membrane, we scrape off the membrane, which is a matter of minutes only, we send in filtered water from the neighboring filter from underneath, and we put on a new filtering membrane also in a few moments. It seldom occurs that any of the sand gets dirty; if it were so, it must be due to the wilfulness or absolute carelessness on the part of the attendants. The renovating of the surface is performed in less than an hour, instead of four or five days. This advantage will not fail to strike engineers as being of great service in times of emergency.

Among the improvements that we have introduced, and which have been the subject of applications for patents, are:

First, means to prevent water passing improperly filtered between the sand and retaining walls.

Second, in large filter beds as hitherto constructed and operated,

the surface is anything but even and regular; however carefully the surface is leveled by the men who tread on it, when water comes in many protuberances and sink-holes are produced, and the filtering membrane forms in a most irregular manner, very little stopping on the protuberances and much in the holes. We have provided for the perfect leveling of the surface in a manner that we shall explain later on.

Third, there is a phenomenon in filtration through granular beds which has exercised the minds of many engineers. Water in motion holds air in solution or suspension, and keeps it as long as the velocity has not fallen below a certain point; but when the velocity has been practically destroyed by the resisting action of the filtering materials, the air disengages itself, and has a tendency to prevent filtration, or to rise up through the surface. When the filter is filled up at the starting of an operation, the air contained in the sand escapes violently toward the surface, and opens up many passages. We have also provided means for the free escape of the air without breaking the beds.

If, perchance, the large filter beds become polluted with disease germs, as has sometimes occurred in times of epidemic, the cost and trouble of removing all materials, or providing sterilizing liquids in sufficient quantity, render their disinfection practically impossible.

The sectional division of our filtering area enables us, if such happened, to sterilize the filtering materials with suitable sterilizing agents that may be sent from one section to another without being wasted, and thus affording a practical means of keeping the filters always in an aseptic condition.

Since writing the above, two facts have been brought to our notice in the daily press which may be of interest at this juncture. It is reported that the Paris water contains a microbe known as *Bacillus coli communis*, or "colon bacillus," which is evidence of sewage pollution. This is found, not in the waters of the Seine, but in that derived from so-called springs, and which has hitherto been looked upon as so perfect as to be beyond suspicion.

This reminds us of a fact which has been brought to our notice, and which we think worthy of serious consideration. The manager of a large farm in Tunis stated that after a heavy rainfall the wells of his farm gave turbid water, and a week or a fortnight after many of his sheep were down with typhoid fever. This has occurred not

once or twice, but dozens of times; and this would tend to indicate that typhoid fever comes, in the first place, and mostly, from decomposing vegetable matter, such as leaves, rotten roots, and the like.

The fact is that it is practically impossible to get enough real spring-water in the neighborhood of any large city for its supply. Much of what is baptized as spring-water comes from very shallow springs and rivulets, collected together by drains. Usually in times of rainfall the water of these springs and rivulets becomes turbid, showing that there is surface pollution. Let us not, therefore, indulge in the dreams of getting an adequate supply from ideal springs, which are so rare, and let us apply ourselves to the art of filtration for assuring cities a good water-supply.

The second item of interest comes from Camden, N. J. The pure artesian water is now delivered to the city, but already the inhabitants complain that the water in the middle of the day does not rise to the second floor. Pumps, like filters, work at a fairly even rate, while the consumption varies from hour to hour, sometimes in the proportion of one to two, and more. This strengthens our argument that large reservoirs are needed for the storage of filtered water, and these should be covered.

It may not be out of place to sound a note of warning to those who think that they might, by laying drains into the sandy soil on the banks of the rivers, obtain an unlimited quantity of river-water naturally filtered. This has been done over and over again, particularly in France, but with disastrous results in each case. For a time the drains give really good water, but the banks and bottoms of the rivers through which the water passes become choked with mud, like the banks and bottoms of canals, and if water still runs through to the pump wells, it must get there through fissures which widen constantly, and become regular channels for the passage of the raw water to the pumps.

We observed this fact in the so-called filtering galleries of Nancy, in the east of France. Drains were established in the natural gravel soil bordering the Moselle River, and for a short time gave good water; but it was not long before the meadows that were supposed to filter the water became quite dry, so that wells sunk six or ten feet below the level of the drains showed no water at all, and yet water was running through the main galleries. It was simply coming

direct from the river through fissures which had gone on enlarging themselves gradually.

The city of Nancy has been for years subject to terrific typhoid epidemics, and the city reservoirs have at all times a considerable quantity of mud that practically comes direct from the river.

If we go to distant lakes where there is no sewage pollution, the water must still be filtered on account of the dead leaves and surface drainage which flow into them. The German Government has made laws for all surface-waters from any source being filtered before distribution in towns.

Attention may also be drawn to a fact which has not received sufficient attention. We are told that consumption, small-pox, diphtheria, scarlet fever, and other diseases are contagious, and are conveyed by dried excretions, secretions, and exfoliations from person to person. We are forbidden to spit in the cars, and told to sterilize linen, to fumigate or disinfect sick-rooms, and to take all sorts of precautions against the dust which is supposed to contain these deadly germs. We admit this; but we would like to observe that we are partly protected against the air germs by the natural filter in the nostrils, and by the epithelium and mucous membrane of the throat, which is so easily irritated by foreign matter; but we are not protected in any way by nature against these same germs when they are brought to us in our food and in our drink.

When rain or snow falls, these germs in the air are brought down to the ground to join those already there, and with more rain or thaw they are all washed down into the rivers or shallow springs. There is plenty of food for them in the water in the shape of vegetable and animal matters in decomposition.

Any kind of coarse filtration which would remove dead leaves and other big particles of organic matter before the water goes into the reservoirs would do some good.

Mechanical filters, using no coagulant, are said to remove fifty per cent. of bacteria, with a speed of filtration of 120,000,000 gallons per acre per day.

Of course, this is not a sufficient amount of purification; but we want it to be understood that even then it were better to filter water with this small bacterial efficiency than to do nothing. But such efficiency is not sufficient, and we propose examining in detail the

standard adopted by the German Imperial Board of Health. The following are the rules laid down:

In judging of the quality of a filtered surface-water the following points should be especially observed:

The operation of a filter is to be regarded as satisfactory when the filtrate contains the smallest possible number of bacteria, and not exceeding the number which practical experience has shown to be attainable with good filtration at the works in question. In those cases in which there are no previous records showing the possibilities of the works and the influence of the local conditions, especially the character of the raw water, and until such information is obtained, it is to be taken as the rule that a satisfactory filtration will never yield an effluent with more than about 100 bacteria per cubic centimeter.

A distinct understanding must exist as to the method of analysis that shall be employed. For instance, while Koch with his method will obtain 100 bacteria per cubic centimeter, Miquel, by his dilution system, will find 1000 or more.

The filtrate must be as clear as possible, and in regard to color, taste, temperature, and chemical composition, must be no worse than the raw water.

The Imperial Board appears to be very liberal in asking that the color, taste, and chemical composition be no worse than the raw water. At first sight this seems too much liberality. This is, no doubt, to guard against the use of materials that might give color or taste to the water, as also against chemicals that might increase the hardness and corrosive action of the water, or others known to be detrimental to health, such as barium salts, which have been sometimes recommended for the purification of hard waters.

"To allow a complete and constant control of the bacterial efficiency of filtration, the filtrate from each single filter must be examined daily. Any sudden increase in the number of bacteria should cause a suspicion of some unusual disturbance in the filter, and should make the superintendent more attentive to the possible causes of it."

"Filters must be so constructed that samples of the effluent from any of them can be taken at any desired time for the bacteriologic examination."

"In order to secure uniformity of method the following is recommended as the standard method of bacterial examination:

[The nutrient medium consists of

Agar-agar,	12 grams
Liebig's extract of beef,	3 grams
Witte's dried peptone,	10 grams
Sodium chlorid,	5 grams
Distilled water,	1000 c.c.

The samples of the water under examination are to be taken of $\frac{1}{10}$ c.c.

The agar is melted at boiling temperature, cooled to 42° C., and mixed with the water as thoroughly as possible in the test-tube by tipping back and forth, and is then poured in a Petri plate, which is kept at room temperature.]

We have in the above method replaced that indicated in the German standard by the process used in the laboratories of the city of Philadelphia.

"The resulting colonies are counted after forty-eight hours, and with the aid of a lens. If the temperature of the room in which the plates are kept is lower than 20° C., the development of the colonies is slower, and the counting must be correspondingly postponed. If the number of colonies in 1 c.c. of the water is greater than about 100, the counting must be done with the help of Wolffhügel's apparatus."

"The person intrusted with the carrying out of the bacterial examinations must present a certificate that he possesses the necessary qualifications, and, wherever possible, he shall be a regular employee of the waterworks."

"When the effluent from a filter does not correspond with the hygienic requirements, it must not be used unless the cause of the unsatisfactory work has already been removed during the period covered by the bacterial examination. In case a filter for more than a very short time yields a poor effluent, it is to be put out of service until the cause of the trouble is found and corrected."

"It is, however, recognized from past experience that sometimes unavoidable conditions (high water, etc.) make it impossible to secure an effluent of the quality stated in the first section. In such cases it will be necessary to get along with a poorer quality of water, but, at the same time, if the conditions demand it (outbreak of an epidemic, etc.), a suitable notice should be issued."

"Every single filter should be built so that when an inferior effluent results which does not conform to the requirements, it can be disconnected from the pure water pipes and the filtrate allowed to be wasted. This wasting should, in general, take place, so far as the arrangement of the works will permit:

"(1) Immediately after scraping a filter, and (2) after replacing the sand to the original depth. The superintendent must himself judge, from previous experience with the continual bacterial examinations, whether it is necessary to waste the water after these operations; and, if so, how long a time will probably elapse before the water reaches the standard purity."

"The best sand filtration requires a liberal area of filter surface, allowing plenty of reserve to secure, under all local conditions, a moderate rate of filtration adapted to the character of the raw water."

"Every single filter shall be independently regulated, and the rate of filtration, loss of head, and character of the filter shall be known. Also each filter shall by itself be capable of being completely emptied, and, after scraping, of having filtered water introduced from below until the sand is filled to the surface."

"The velocity of filtration in each single filter shall be capable of being arranged to give the most favorable results, and shall be as regular as possible, quite free from sudden changes or interruptions. On this account reservoirs must be provided large enough to balance the hourly fluctuation in the consumption of water."

"The filters shall be so arranged that their working shall not be influenced by the fluctuating level of the water in the filtered water reservoir or pump-well."

"The loss of head shall not be allowed to become so great as to cause a breaking-through of the upper layer on the surface of the filter. The limit to which the loss of head can be allowed to go without damage is to be determined for each works by bacterial examination."

"Filters shall be constructed throughout in such a way as to insure the equal action of every part of their area."

"The sides and bottoms of filters must be made water-tight, and special pains must be taken to avoid the danger of passages or loose places through which the unfiltered water on the filter might find its way to the filtered water channels. To this end special pains should

be taken to make and keep the ventilators for the filtered channels absolutely tight."

"The thickness of the sand layers shall be so great that under no circumstances shall it be reduced by scraping to less than thirty centimeters (twelve inches), and it is desirable, so far as local conditions allow, to increase this minimum limit. Special attention must be given to the upper layer of sand, which must be arranged and continually kept in the condition most favorable for filtration."

"For this reason it is desirable that, after a filter has been reduced in thickness by scraping and is about to be refilled, the sand below the surface, as far as it is discolored, should be removed before bringing on the new sand."

The water of the Schuylkill River contains a number of distinctly color-producing microbes, such as the *Bacillus janthinus* (dark blue), which are not in the air, and, we would suggest that the analysis be qualitative, so as to be able to distinguish between the water germs and the air germs, which multiply in the channels of the filtered water, or may fall into the tubes or plates on which they are cultivated. A simple quantitative analysis does not afford, in our opinion, a sufficiently correct standard.

The recent outbreak of typhoid fever in Philadelphia emphasizes the objections raised against settling reservoirs. The nine wards supplied by water from Queen Lane reservoir have 239 cases out of a total of 427 for the whole city. The three wards which have escaped are supplied from Fairmount and the Delaware River.

The explanation of this striking difference is, in our opinion, this: At the Queen Lane pumping station a considerable current is induced by the draft in comparatively still water of 70,000,000 gallons of water a day. The bulk of the floating mud is thus engulfed and pumped up into the reservoir, which must now have a foot or more of mud deposit.

When it is desired to make a bacterial infusion, leaves, hay, or straw are put into stagnant water, and a plentiful crop grows. This practically takes place on a large scale in the Queen Lane reservoir. At Fairmount, on the contrary, the water is spread out over the whole length of the dam. It is taken at the surface of a small section of the dam. There is no engulfing of mud; on the contrary, the forebay

acts as a settling area. The minimum of debris is pumped up. The bacteria in the Fairmount reservoir have less food than in the Queen Lane reservoir, hence the less pollution. This is another reason why the Fairmount pumping station should not be given up. And we would strongly advocate the continuous filtering decantation of the Queen Lane water near the river, and before it is raised by the high level pumps.

Great agitation is going on to urge Councils to favor schemes to bring water from far away. We see no objection to any such proposition. But this means the expenditure of a great deal of money, and years of work. Meanwhile hundreds of people die, and thousands are sick. Delay in improving the present water-supply by filtration is simply criminal.

A man is hanged for a single murder. Shall we stand by and watch thousands of murders by polluted water without raising a hand and a voice against delay in filtration? I do not think a single member of this Club will be so fearfully heartless. That the Schuylkill water can be rendered pure is here shown by the appearance of the samples on the table and the various tests that have been made of it before and after filtration.

DISCUSSION.

E. K. LANDIS.—What is the ratio of the pathogenetic bacteria in the filtered to the unfiltered water?

MR. MAIGNEN.—The following table shows the number of points of microbic life before and after filtration, at the rate of twelve million gallons per acre per day:

1898				BEFORE FILTRATION.	AFTER FILTRATION.	PERCENTAGE OF REDUCTION.
September	27,	Filter-bed	No. 2.....	610	50	91.8
"	29,	"	" 1.....	3,200	175 *	94.6
October	12,	"	" 2.....	1,040	30	97.2
"	17,	"	" 2.....	1,240	30	97.6
"	21,	"	" 1.....	960	45	95.3
"	29,	"	" 2.....	1,265	35	97.3
December	21,	"	" 1.....	4,960	30	99.4
"	23,	"	" 1.....	2,930	90	96.9
"	27,	"	" 1.....	"	14	99.5
"	28,	"	" 1.....	"	65	97.8
"	30,	"	" 1.....	3,860	55	98.6
1899						
January	7,	"	" 1.....	4,137	84	98.0
"	13,	"	" 1.....	1,500	72	95.9
"	21,	"	" 1.....	4,770	90	98.0
		Averages.....		2,539	61	96.99

* The filter-bed had been worked the day before at the rate of forty million gallons as an experiment.

Among the many species of microbes that are in the unfiltered water, we have, so far, identified only about a dozen, as follows:

Bacillus janthinus, *B. violaceus*, *Micrococcus roseus* (pinkish), *B. latericeus* (brick-dust), *B. luteum* (orange), *B. fluorescens*, *B. ramosus*, *B. vermicularis*, *B. proteus* (several varieties), *B. ubiquitus*, *B. coli communis*, *B. subtilis*. Several species forming yellow colonies were not identified.

In the filtrate we have never found more than a few species: *B. proteus*, *B. ubiquitus*, *B. luteus*, *B. vermicularis*.

All these are also found in the air, and we have never found any pathogenetic or suspicious bacteria in the filtrate.

MR. LANDIS.—How about typhoid bacillus?

MR. MAIGNEN.—We have not sought the typhoid bacillus in the unfiltered nor in the filtered water, because to identify the typhoid germ is, as every one knows, very difficult and tedious. We prefer following the plan adopted, not only abroad but also in this country, by the best authorities, and by the Army Medical Department, which consists in applying to the unfiltered water test organisms developing distinctly colored colonies, and watching their passage or no passage through the filter.

We have selected for this purpose the *Bacillus janthinus* (dark blue colonies), *Micrococcus roseus* (pinkish colonies), which we have isolated from the Schuylkill water and cultivated for the purpose of filtration tests.

The following are the results we have obtained:

1898.	MICROCOCCUS ROSEUS.	BEFORE FILTRATION.	AFTER FILTRATION.
September 27,	Filter-bed No. 2	350	5
" 29,	" " 1	6,510	20
" 29,	" " 2	200	0
October 5,	" " 1	19,600	0
	BACILLUS JANTHINUS.		
October 7,	Filter-bed No. 1	820	0

We have also examined what species of bacteria were in the atmosphere surrounding our experimental plant and our laboratory, and the following are the observations we have made (January 24, 1899):

AIR PLATES EXPOSED.	COLONIES ON PLATES.	OBSERVATIONS.
One second	Sterile.	
One minute	2	1 *B. subtilis*.
Five minutes	7 colonies, 4 molds.	*B. luteus*, *B. aurantiacus*, *B. proteus vulgaris*.
Ten minutes	10 colonies.	*B. ramosus*, *B. proteus*.
Fifteen minutes	18 colonies, 5 molds.	

All the above plates were exposed on a table in the laboratory.

One-half hour, in office on ground floor	37 colonies, 8 molds.
One-half hour, in laboratory	48 colonies, 12 molds.
One-half hour, on floor of laboratory	63 colonies, 10 molds.
One-half hour, laboratory window on street, temperature 38° F.	466 colonies. Chiefly *B. helvolus* (yellow).

Among the species identified in our air plates are the following: Colored, *B. prodigiosus* (red), *Staphylococcus pyogenes aureus* (orange); pink (not identified); white, *B. proteus*, *B. luteum*, *B. ubiquitus*, *B. vermicularis.*

Most of those in the air develop pink and yellow colonies. *B. janthinus* is never found in the air, but it is frequently observed in the Schuylkill water, and would seem to be a good test organism for Philadelphia water.

WM. EASBY, JR.—The Louisville inquiries into the operation of high-rate filters cover a period of about two years, and embrace two successive and independent series of investigations. The first series showed that the systems, as operated by the representatives of the companies which installed them, required for the coagulation of the applied water from 1 to 10 grs. of sulphate of alumina per gallon, with an average of about three grains, the variation in the quantity of coagulant necessary being due principally to the variation in the quantity and nature of the matter in suspension in the raw water. Little or no provision was made for sedimentation before the coagulated water was applied to the sand-bed of the filter. This was found to be the greatest defect in all of the systems which were installed. In the series of investigations which was carried on independently by the Louisville Water Co. provision was made to secure more economic coagulation than in the first series by allowing the chemical applied for this purpose a longer time for decomposition before the treated water was applied to the sand-bed. It was found that under these conditions the necessary quantity of sulphate of alumina varied from ½ to 5 grs. per gallon, with an average of 1¾ grs. By comparing this result with that obtained in the first investigations, it will be seen that an important saving in operating expenses was effected. As a further result of coagulation and sedimentation, the indications were that if these processes were carried to their economic limits the water reaching the sand-beds would be of a uniform character, and, consequently, the installation of a large reserve filtering area would not be necessary in maintaining a fixed rate of filtration. Mr. Geo. W. Fuller, under whose directions these investigations were made, concluded that for the daily water-supply of Louisville, amounting to 25,000,000 gallons, complete coagulation and sedimentation, in connection with the use of mechanical filters, would effect a yearly saving (on the cost of installation and operation, as shown by the first series of investigations) which, if capitalized at five per cent., would amount to $700,000.

MR. MAIGNEN.—I should like to observe that the Louisville Company experimented as far back as 1884 and 1885 with so-called slow sand filtration. Perhaps Mr. Easby will be able to enlighten us on the results obtained. I may add that, from recent information received, the officers of the Louisville Company, after so much experimenting, have not yet completely made up their minds as to the exact kind of filtration they will adopt.

As to the so-called mechanical filtration, which has sometimes been spoken of for application to the Queen Lane reservoir, we can not help pointing out that the cost of such a system would, if we are to judge by the reports of the Louisville experiments, be very considerable; particularly if we take into consideration the raising of the water, its treatment with alum, and its filtration before use for

washing the sand. In some periods as much as seventy-five gallons of filtered water are required to wash the sand which has filtered one hundred gallons.

MR. EASBY.—The failure of the slow sand filtration method as tested in 1885 in Louisville was due to the fact that the Ohio River water very frequently carried a large amount of finely divided clay, which did not stay on the surface but entered the body of the filter-bed, from which position it could not be economically removed. This difficulty is overcome in high-rate filters by the mechanical agitation of the sand-bed in connection with a reverse current through the filter.

E. M. NICHOLS.—About a year ago there was a resolution before the Club offering the opinion or judgment that we should, as a club, look into the matter of water filtration. This was shortly after the U. G. I. had gotten hold of the gas-works. It does seem to me that if there is any organization in the city competent to take up the question of purification of water it is the Engineers' Club of Philadelphia. There are certainly men in this Club to go at it from almost any standpoint. One thing has occurred to me, though, and that is that, as engineers, we pay little attention to professional ethics. We get all sorts of opinions, from all sorts of men, printed daily in the newspapers, and I think that this Club should get down to executive session, meeting, say, as a lot of doctors, and do their quarreling there, and give out some definite opinion, so as not to get the public mixed up or the engineers in the council mixed up. It might settle the question a little sooner. So far as the purification of water is concerned, it is not an experiment. There is not a civil engineer in this Club that has had as much as ten years' experience but what is competent to call together enough ability in a consulting way to arrive at a plan which is not only economical, but is efficient in every respect. We know that the head of the Water Bureau to-day is one of the best members of the Club. He goes at it in a good, common-sense way. The first thing he says, "You are using about three times as much water as you need; if you will prevent this useless waste of water, then I will take the money that you have got and I will give you just as good water as you can get anywhere." These two propositions are self-evident. I know from my own experience that it is. I was for two or three years superintendent of a waterworks in a town in the State of Wisconsin. The water was taken from artesian wells. The maximum capacity of these wells was about 1100 gallons per minute, or a little over 1,500,000 gallons per twenty-four hours. We had arrived at the point where it was either a case of reducing the consumption or getting more wells. They finally decided, after a long talk, to adopt the meter system, with the result that by metering less than twenty-five per cent. of the services we reduced our consumption over forty per cent. I have not read the report of the last year or two from the town, but I am under the impression that to-day, with double the number of services, the amount of water consumed is less than it was prior to the installation of the meter. Not only that, but each service costs less to the consumer, and the net income from the operation of the works is about fifty per cent. more than it was. This is just one of the many cases that might be cited, and, as Mr. Trautwine has pointed out, we have enough pumping plants in this

city to have engines stand idle all the time if the water were only used as it should be; and when you take into consideration the cost of filtering so much water to waste, I think that he takes a proper view of the subject. But what I started out to say was that there is too little attention paid to professional ethics as engineers. It is simple enough for this Club to make its effort felt much better than it ever has been before; there is not a paper in town but what would cooperate with it and help it out. As the matter now stands, everybody is an engineer, everybody knows how it should be done, and they talk all sorts of schemes and nonsense. One man may be in the employ of a corporation, and he has got a scheme; they go to the Councils with it, and possibly the Councils see a scheme in it, and we get a new ordinance started at once. I believe this Club ought to take a little more interest from an engineering standpoint, and see if we can not help solve the matter.

SILAS G. COMFORT.—At a meeting of the Club some five or six years ago, Dr. Leffmann presented a paper in which he emphasized the importance of the filtration of water. Since that time we have listened to papers advocating the procuring of the water-supply of Philadelphia from various localities. At times the matter of filtration has been considered as of but secondary importance. Now, however, the question has narrowed itself to the necessity of filtration, irrespective of the location of the supply. We should congratulate our presiding officer (Dr. Leffmann) and ourselves, as members of this Club, on this happy outcome of years of discussion.

In this connection it is well for us to remember that when the great cholera epidemic occurred some years ago, the two adjacent cities of Hamburg and Altona were unequally affected. The water-supply of Altona was filtered, that of Hamburg was not. Cholera in Hamburg went right up to the boundary line of Altona, and there stopped. Prof. Koch gives the following: At one point near the boundary line is a large yard, known as the Hamburger Platz. It contains two rows of buildings, containing seventy-two separate tenements, occupied by some 400 people, belonging almost wholly to those classes who suffered most from cholera in Hamburg. But while cholera prevailed all around, not a single case occurred among the many residents of this court during the epidemic. And why? Because, for some reason, these dwellings were supplied from the Altona mains. This was the only spot in Hamburg that received Altona water, and it was the only part of Hamburg in which was aggregated a population of the class in question which escaped the cholera.

Hamburg now has filtered water. After the epidemic, work was pushed night and day on the plant. May Philadelphia act before necessity compels her to do so!

In conclusion, I repeat we should congratulate ourselves that it has been stated to-night that Philadelphia must have filtration, and that the only question to be considered is the details of the plant.

A SAND FILTER-PLANT.

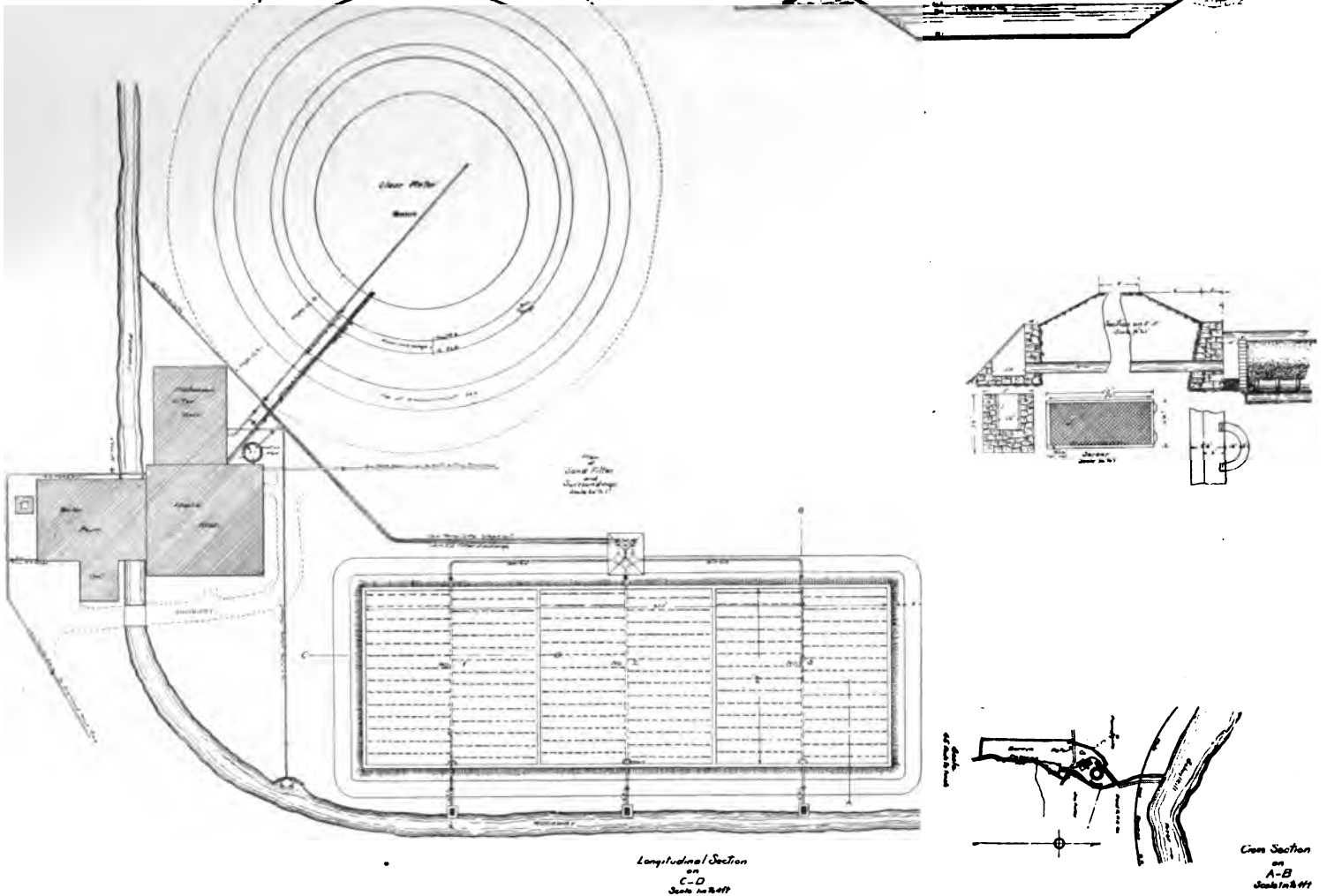
J. W. LEDOUX.

Read February 18, 1899.

THE American Pipe Manufacturing Co. has lately constructed for the Berwyn Water Company, at the Pickering Creek pumping station, a sand filter-plant having a nominal capacity of one and one-half million gallons per day. With the exception of some outside earthwork, grading, sodding, and a floor in the gate-house, which were postponed on account of the weather, the work was completed and the filters put in operation about January 1, 1899.

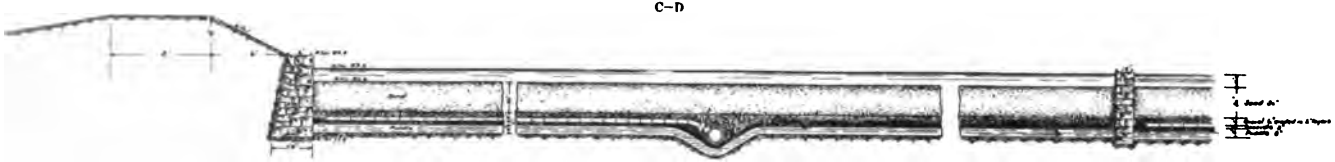
Previous to that date the water was filtered through mechanical filters of the Warren gravity type having a nominal capacity of 750,000 gallons per day, and located in a building forming an extension of the main pumping station. The mechanical filters have always given satisfaction, and the water furnished by this company to their consumers along the main line of the Pennsylvania Railroad from Glen Loch to Bryn Mawr is justly celebrated for its uniform clearness and purity. The consumption of water from the Pickering Creek station is less than 500,000 gallons per day; but having in mind future increase, and wishing to have the two best recognized systems of filtration for constant comparison, the Berwyn Water Company installed the sand filter-plant, which, it is believed, has been designed and constructed according to good modern practice.

The sand filters are built in three compartments, each containing 7500 square feet of effective filtering area, and arranged so that any one can be cut out or operated with wasting of water without interfering with the others. About 600 feet to the south of the filters is a masonry dam across Pickering Creek from which the water flows down the head race to the pumping station. Opposite the center of each filter compartment is located the screen chamber, influent pipe, and chamber as shown in the general plan. The top of the influent chamber is on a level with the top of the sand. A vertical section through filter-beds shows 30 inches of sand, 6 inches of gravel, 3 inches of concrete,

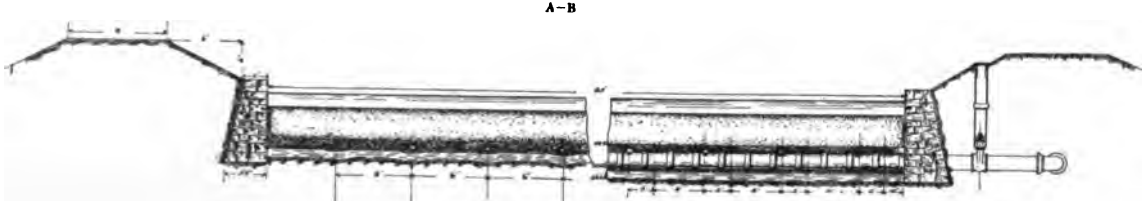


GENERAL PLAN.

C–D



A–B



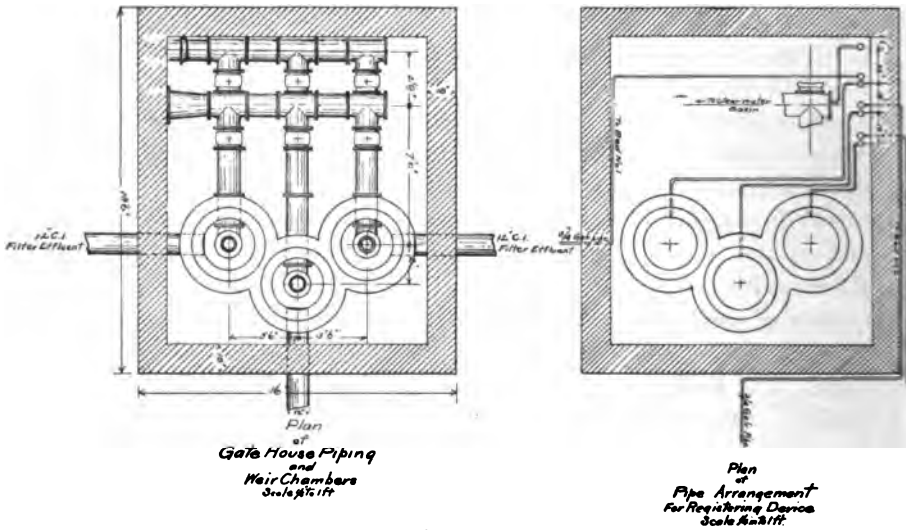
SECTIONS.

and 8 inches of puddle. The main drains are vitrified bell sewer-pipes 12 inches in diameter, and laid with water-tight cement joints. The laterals are ordinary terra cotta 4-inch tile drains without bells, made in 12-inch lengths and simply butted together. They are spaced 6 feet apart and kept from moving out of place laterally by means of a handful of cement mortar placed under each side of every length.

The laterals are placed in depressions in the concrete, so that there is over each about 4 inches of gravel. The gravel was screened, washed, and graded from pea-size to $1\frac{1}{2}$ inches, the smallest sizes, of course, being placed on top. Just inside the masonry walls the main drains terminate in cast-iron pipe of the same diameters. The side walls and division walls are composed of rubble masonry, consisting of stone from a nearby quarry, and hydraulic cement mortar, one to two. Outside of the masonry retaining walls is the earth embankment, composed of material excavated from the inclosure, which also contained suitable material for puddle. The gravel and sand were dredged from the Delaware River in the vicinity of Gloucester, N. J., towed in barges to a wharf on the Schuylkill near Race Street, and thence shipped via the Philadelphia and Reading R. R. to Phœnixville, whence it was hauled by wagons to the site. The quality of sand was such that no washing or screening was required. The gravel had to be washed, screened, and graded to the proper sizes. The sand was frequently tested, and proved very uniform in quality. One test was to determine the quantity of filtered water per acre that would pass through one foot of the sand under an effective head of 12 inches of water. The average showed about sixty million gallons per acre per day. The effective size was $\frac{25}{100}$ mm. and the uniformity coefficient $1\frac{82}{100}$. Many samples of different qualities of bar sand and Jersey sand were examined before deciding on Gloucester white sand. A good quality could have been obtained near Cape May, known as Cape May white sand, but it proved too expensive, and little if any better than that adopted. A sketch of the apparatus for testing the rate of percolation is shown. Another apparatus, nearly as good and much cheaper, is made by placing in a cylindrical tin tube, three or more inches in diameter and two feet long, two bottoms about an inch apart. The upper bottom is a brass cloth sieve, of No. 40 mesh, soldered in place. Between the two bottoms a half-inch nipple, to which is attached a piece of rubber

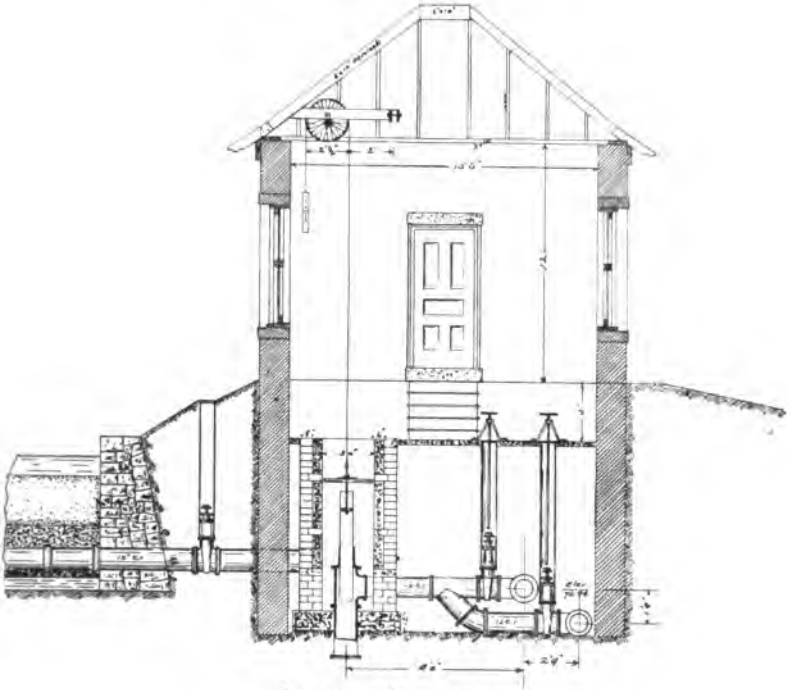
hose, is placed. In this tube is placed the required sand to a depth of one foot. The cylinder is then set under a spigot and the open end of the hose raised until the difference in level between top of cylinder and of hose is one foot. The spigot is then opened, the water falling on a lip at top of cylinder so as not to disturb or agitate the surface of sand, and the rate of percolation may be measured by means of a gallon measure held under end of tube, always being careful that spigot is opened wide enough so that a small amount of water constantly runs over the top of cylinder.

The effective size of the sand grains is determined as follows: A

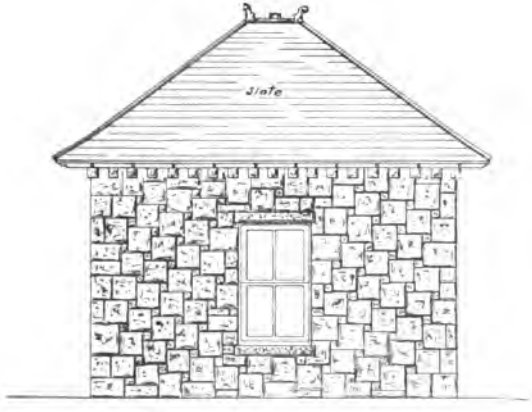

12" C.I. Filter Effluent
12" C.I. Filter Effluent
Plan of Gate House Piping and Weir Chambers
Plan of Pipe Arrangement For Registering Device

DETAILS.

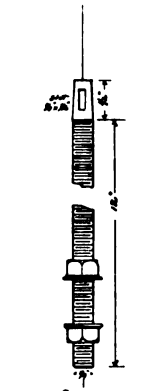
series of, say, eight screens is provided, numbering from 30 to 100 meshes per lineal inch; each is tested with standard silicious sand, by sifting a handful thoroughly until apparently no more will pass through. By shaking vigorously for a time a sufficient number of grains will pass through, say, a thousand. Weigh these carefully and then count them. The weight divided by the number will give the weight of each grain. Now, by assuming each grain to be a sphere, and the specific gravity to be 2.6, the diameter can be determined in millimeters. The sieve is then stamped with the number, and all the other sieves tested in the same way. Now weigh out,

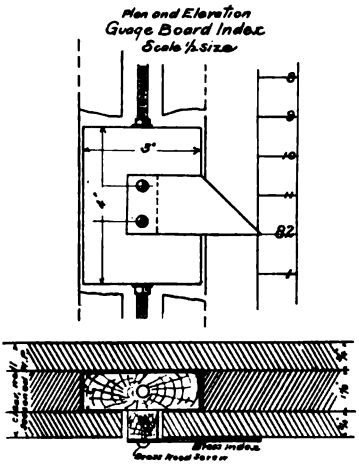


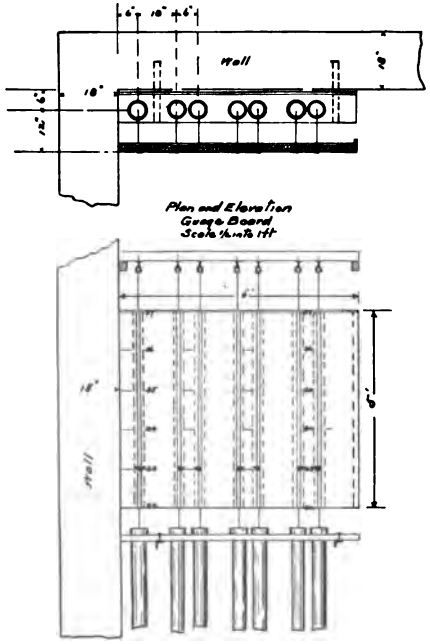
DETAILS OF GATE-HOUSE.

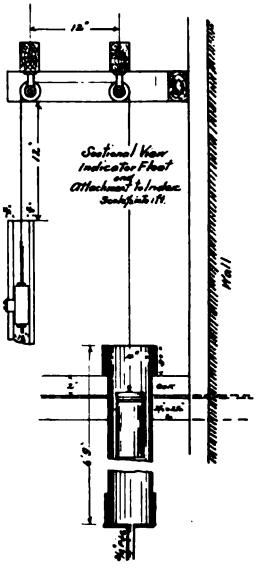


End Elevation
of
Gate House


Screw
Index Counterbalance
full size

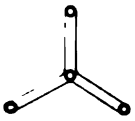

Plan and Elevation
Guage Board Index
Scale ½ size
3"
4"
82
Brass index
Cross head screw


Wall
Plan and Elevation
Gauge Board
Scale ¼ inch to 1 ft
Wall

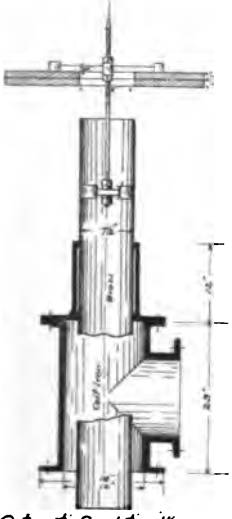

Sectional View
Indicator Float
and
Attachment to Index
Scale full size
Wall

DETAILS.

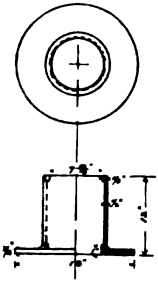
Composition Metal
For Weir Tube
Scale 4 in To 1 ft



Composition Metal
For Float Attachment
Scale 1 in To 1 ft

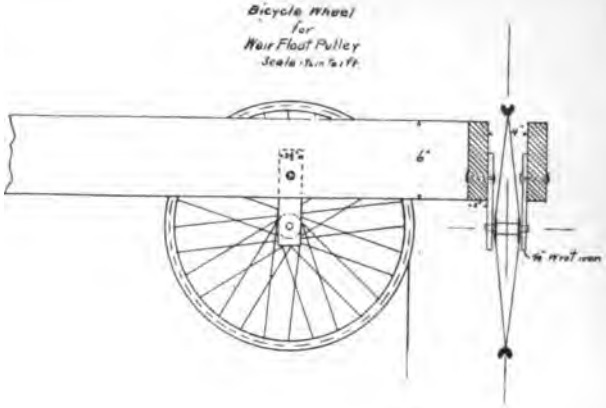


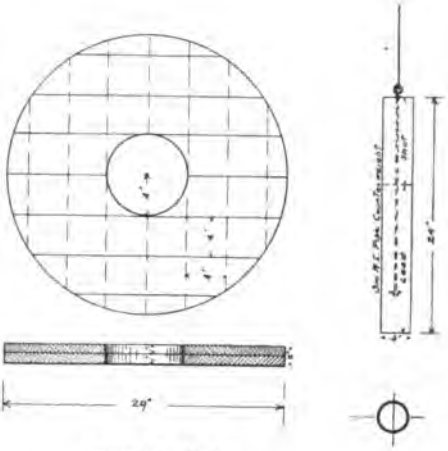
Automatic Regulating Weir
Scale 1 in To 1 ft



Cast Iron Sleeve
with brass bearings
Regulating Weir
Scale 1 in To 1 ft

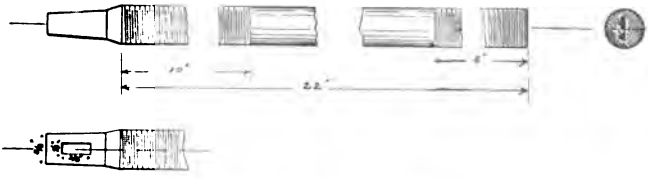
Bicycle Wheel
for
Weir Float Pulley
Scale 1 in To 1 ft





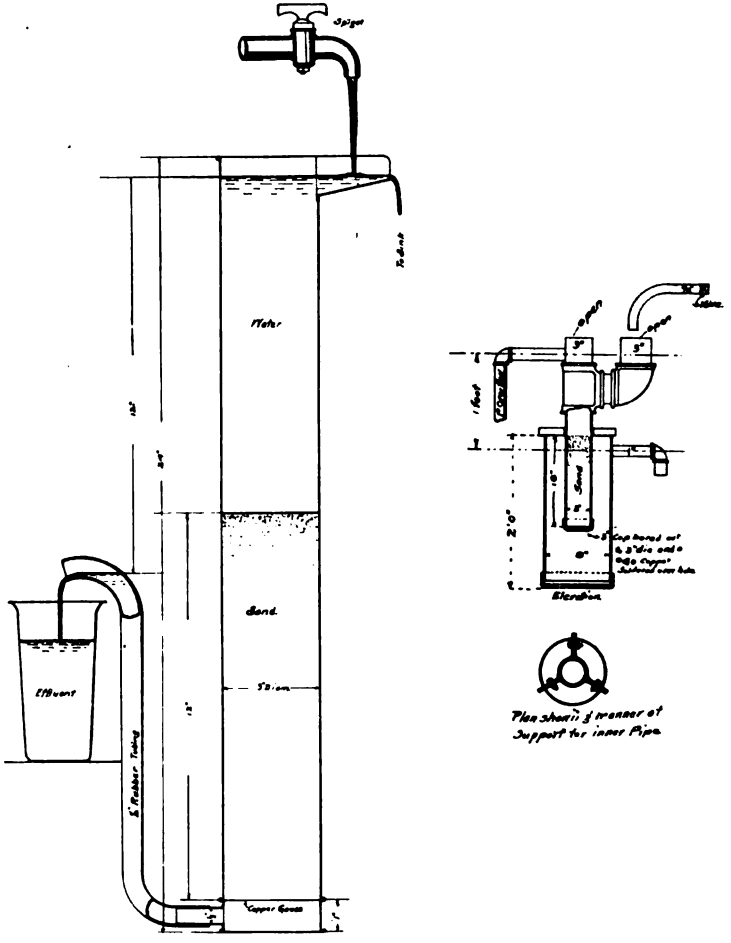
Red Cedar Float
1 in To 1 ft

Telescoping Weir Tube
No 11. B.W.G. Drawn Brass
Scale 1 in To 1 ft



Composition Adjusting Screw for Float
Full size

say, ten grams of the sand to be tested and try it on each sieve until one is found that will pass through only ten per cent., or one gram. The number on that sieve is the effective size, providing our assump-



Apparatus for Testing Rate of Percolation.

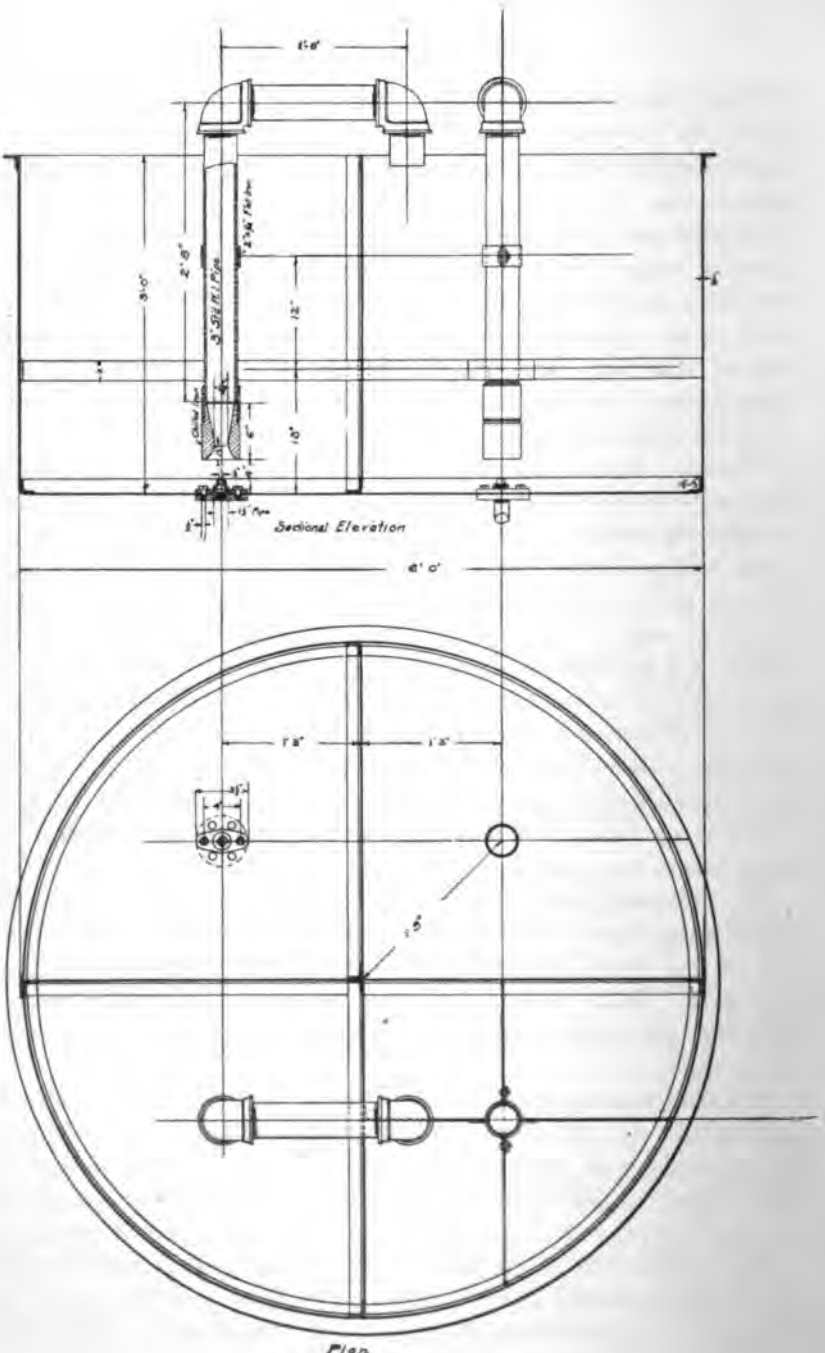
tion of the specific gravity is correct, which it should be if the sand is of proper quality. The uniformity coefficient is the ratio of the size of the sieve that will pass through sixty per cent. to the size that

will pass through ten per cent. No dependence whatever can be placed on the trade number of the sieves. There are no other features about the filter-beds and their construction requiring further explanation.

By reference to the plans it will be seen that provision is made to secure a uniform rate of percolation through the filter-beds. The regulating apparatus consists of a brass tube open at both ends and hanging to a float which rises and falls with the water-level in the effluent chamber. The top of the tube may be considered a submerged circular orifice or weir, whose distance from the float is constant but adjustable. The float and sliding tube are counterweighted as shown. As the sand bed becomes clogged by sediment deposited thereon, the water-level in effluent chamber will lower, and thus increase the effective head, or difference in level between the water on filters and in effluent chamber. When this difference becomes four feet, the surface of the sand bed must be scraped. Ordinarily, this period, at normal rate, will be twenty or more days, which is the length of time between scrapings. In the gate-house an indicator board is provided having seven indicators, one for each filter-bed, one for each effluent chamber, and one for the clear water basin. The difference in level between the water on filter-bed and that in the corresponding effluent chamber, which also indicates the loss of head, is shown at a glance. The board is graduated in feet and inches from ocean tide as a datum.

The indicators slide in vertical grooves and are attached to No. 26 copper wires which run over brass pulleys. Attached to the other end of the wires are floats composed of 3-inch nipples capped at both ends. These work in float pipes having half-inch pipe connections with the water on filter-beds, in effluent chambers, and in clear water basin.

The sand-washing apparatus is worthy of description on account of its simplicity and effectiveness. The plan shows clearly the principle, but the number of compartments will be increased to six instead of four. Sand scraped from the filter-beds is shoveled or otherwise conveyed into the first compartment, into which also runs a stream of water. The jet carries the sand up through the vertical pipe into the second compartment, and the dirty water flows over the top to a depression connected with the waste-pipe. In the same manner the



SAND-WASHING APPARATUS.

sand is forced by jets successively through all the compartments, and finally through a pipe to the point where it will be stored or back to the filter-bed at will. The pressure on the jet-pipes is about twenty pounds. With ¼ of an inch jets three tons per hour can easily be washed clear with this apparatus. The actual cost of the whole work is as follows:

FILTER-BEDS.	COST PER UNIT.	COST.
6772 cubic yards excavation, including 1850 yards for grading,	0.241	$1630.81
$528\frac{3}{10}$ cubic yards stone masonry filter basin,	5.541	2927.31
$2\frac{4}{10}$ " " brick " " "	9.16	21.98
$304\frac{5}{10}$ " " concrete " " "	6.153	1873.43
2432 square yards plastering and forming gutters,	0.2428	591.60
3200 lineal feet four-inch lateral tile drains, in place,	0.0648	207.20
246 " " twelve-inch collecting tile drain, in place,	0.654	160.80
286 lineal feet twelve-inch terra cotta clean-out drain, in place,	1.198	342.64
281 lineal feet twelve-inch cast-iron inlet and outlet pipes,	1.5714	441.57
200 lineal feet fourteen-inch cast-iron filter discharge,	2.1918	438.36
542 cubic yards puddle,	0.709	384.63
$655\frac{65}{100}$ tons gravel, in place in filter bottom,	2.115	1386.62
$2696\frac{234}{1000}$ tons sand, " " " "	1.639	4420.10
GATE-HOUSE.		
$97\frac{2}{10}$ cubic yards stone masonry,	7.234	703.07
$10\frac{75}{100}$ " " brick "	7.380	79.33
$125\frac{3}{10}$ " " excavation, 30 cubic yards rock and $95\frac{3}{10}$ cubic yards earth, including back fill,	0.985	123.43
Roofing, woodwork, and painting,		210.81
9584 pounds flange pipe, gaskets and bolts, twelve-inch, in place,	0.0309	296.26
Registering and weir apparatus in place,		272.45
Six- to twelve-inch valves, with boxes and hand wheels,		254.69
Three intake screens,		39.50
Superintendence and engineering,		729.00
Incidentals,		1000.00
		$18,535.59

DISCUSSION.

JOHN C. TRAUTWINE, JR.—I am particularly interested in Mr. Ledoux's statement that, in constructing a slow sand filter alongside its rapid or "so-called mechanical" sand filter, his company was actuated by the wish "to have the two best recognized systems of filtration for constant comparison." In thus recognizing and acting upon the value of practical experiment, on a working scale, as an aid in determining the best line of procedure in filtration, Mr. Ledoux is following exactly the course which I have always recommended in connection with the Philadelphia water-supply. Recognizing how much we have to learn in connection with the behavior of our river waters at Philadelphia before we can safely proceed with the expenditure of millions in the construction of filter plants for the entire city, I urged, three years ago, the construction of a practical experimental plant in connection with some one of our smaller systems, precisely as Mr. Ledoux has done; and I have ceased not to urge this plan annually ever since. Mr. Ledoux does not state what expenditure of time and labor was required to bring his Board of Managers to see the advisability of this course.

It would be interesting to learn whether alum or other coagulant is used in connection with the Pickering Creek or other rapid or "mechanical" sand filters under his charge; and, if so, to what extent his company's victims have suffered from the dire ills which, we are told, inevitably follow in the wake of such practice.

In the absence of the plans, it is practically impossible to discuss intelligently the details of the plant. Seeing nothing stated to the contrary, I assume that the filter is uncovered, and that it will therefore have to take its chances during freezing weather. The value of the experiment would, I think, have been enhanced if a portion of the bed area had been roofed in, so that it might be ascertained, from experience, whether the expense of such roofing is justified by the advantages gained. From the fact that after some twenty years of use of an uncovered slow sand filter at Poughkeepsie the city proceeded to construct a second uncovered bed at the same site, I gathered that in estimating the cost of slow sand beds for Philadelphia a roof covering might be omitted, and in the estimate submitted by Director Thompson to Councils in October last, accordingly made no provision for such covering, which would probably have added about fifty per cent. to the cost of the filter-beds alone. Since then I have been informed that the omission of a roof from the new bed at Poughkeepsie was sorely against the wishes and recommendations of the superintendent, Mr. Fowler, who (although the old filter has been kept working in spite of ice) has experienced much trouble from that source. Nevertheless, the difference in climate between Poughkeepsie and Philadelphia is such that, in my judgment, it would be unwise to assume, without further evidence, that roofing is a necessary adjunct for a filter-bed in this vicinity.

The three beds are said to be of 7500 square feet area each, or 22,500 square feet (say, half an acre) in total area, and the nominal capacity is stated as 1½ million gallons per day. This, with all three beds in operation, would require a rate

of about 3,000,000 gallons per acre per day—a rate which, in my report already mentioned, I have taken as the *maximum.*

Pickering Creek is, of course, free from the anthracite coal-dust pollution which is so serious a matter on the Schuylkill, but it is probable that the filters of both persuasions, will have their share of sediment to take care of in times of flood. This matter of sediment is, in my judgment, one of the most serious with which we have to reckon in designing any system of filtration for Philadelphia, and it is greatly to be regretted that we have thus far been denied all opportunity for informing ourselves in connection with it.

I am interested to note that the actual cost of the filter-bed, taking the nominal capacity of 1½ million gallons per day, amounts to $12,350 per million gallons of daily capacity. In my estimate of last fall, after comparison of the cost of filter-beds in numerous places, and a careful estimate of the cost of such a bed designed in the Bureau of Water, I adopted $12,500 as the probable cost per million gallons of maximum daily capacity, taking the maximum (as already stated) at 3,000,000 gallons per acre per day, or the same as nominal capacity of Mr. Ledoux's filter.

MR. LEDOUX.—In answer to Mr. Trautwine, I can say that we experienced no trouble in that line. Our Board of Directors employ engineers to advise on engineering matters, and in nearly all cases the engineers' recommendations are adopted.

Alum is used with the Warren filters. Usually, fifty pounds per million gallons is sufficient to form a coagulant; and by the aid of filtration at a rate of two gallons per minute per square foot of filtering area, the water is rendered perfectly clear and colorless. When that is accomplished, in my opinion the water is in every respect pure and wholesome. Frequent chemical analyses show the water to be excellent for all domestic and manufacturing purposes.

There are now about thirteen inches of ice on the filters and three inches of water between the surface of sand and bottom of ice. This condition is almost unprecedented, but the filters are working as usual. If the sudden frost had come at the end of a period before scraping, it would have occasioned inconvenience. In that case we should have flooded the ice with hot water. However, under the worst conditions to be anticipated in this climate I would not provide for covering the filter-beds. Last summer we covered our high service distributing reservoir on the North Valley Hill, using brick piers, cast-iron columns, yellow pine girders, joists, and inch flooring, at a cost of fifteen cents per square foot. The reservoir was circular, and 110 feet in diameter.

I strongly believe in preliminary sedimentation to be used in connection with any plan of filtration. In many cases the total cost of operation would be thereby materially reduced, especially when the raw water is usually turbid.

P. J. A. MAIGNEN.—The location of filter plants near dams, as shown by Mr. Ledoux, is very advantageous in many ways. I should like to ask Mr. Ledoux the dimension of his compensation reservoir or pump-well for the filtered water. Concerning the use of alum alluded to by Mr. Trautwine, I would just like to state that this very day I have examined a sample of water from an alum filter

(so-called mechanical filter) erected in one of the large buildings of Philadelphia. Barium chlorid produced a very heavy precipitate, which, as compared with that of the Schuylkill water, showed a great increase in sulfates. Another sample, tested with potassium hydroxid, gave a flocculent precipitate showing a notable quantity of aluminum.

We have been told that chemists do not find any appreciable amount of alum in the filtrate. This word "appreciable" is very elastic. If half a grain of alum is added to the raw water, this small quantity in the unfiltered water will itself be hardly appreciable to chemical tests, and will be put down as "traces" only. The danger, therefore, is not in the use of such small quantities, but in the difficulty of obtaining the result without a greater dose. Another point open to discussion in the use of alum is this: In the so-called mechanical filters in which it is applied, the time allowed for saturation and precipitation is not sufficient for a complete chemical reaction. Thus it is that when a fresh operation is started, aluminum sulfate has to be applied in a "free flow" by pouring into the filter, as the water enters it, a pint of the coagulant containing 911 grains of aluminum sulfate, "in order," says one authority, "to form the filtering layer; after this the alum may be added drop by drop." In either case a great deal of the alum or aluminum sulfate has not, as was said before, had time to be decomposed before filtration, and it must go through the sand very much as it is put in the water.

The filter plant at Pickering Creek is uncovered, and we are told that no trouble has been met with on account of the ice. The water may, indeed, circulate under the ice, and it frequently happens that at this particular time the water is in a comparatively pure state; I have not seen it as clear as it is now within the last twelve months. As long as the river water remains thus clear, there may be no trouble; but let there come a thaw, and then another spell of cold, the filters will get clogged, and it will be practically impossible to cleanse them. In a city like Philadelphia we must not run such risks, and we must hold filters under perfect control the whole time, every day and every night. The only objection made against covered filter-beds is that of cost. If we wish to build arched roofs like the Romans did, we will no doubt run into considerable expense; but why should we not make use of the modern style of construction, and build in concrete and steel? This can be done for less than thirty cents a square foot. Now, if we compare the interest of this investment with the extra expense and trouble of operating uncovered filters in winter and in summer, under rain and snow, with ice and algæ to remove, we will find that the advantage and economy is on the side of the covered beds, and I would not, for one, consider it safe to operate uncovered filter-beds in Philadelphia.

Mr. Ledoux has just told us that the sand he has been using allows 60,000,000 gallons to percolate per acre per day. Will he tell us for how long a time he has carried on his experiment, and what are the successive rates of filtration he obtained? as also what means he has employed to check the flow down to 3,000,000 gallons? As regards Philadelphia, we must not forget that the cost and scarcity of land is a considerable factor in the filter question.

Like Mr. Ledoux, I have found that if the speed of filtration through sand is not checked, a very great speed can be obtained, and I consider 12,000,000 gallons per acre the safe maximum limit. Beyond this, in addition to the more frequent cleansings entailed, a greater flow would pack the sand closer and closer and prevent filtration. Mr. Hazen, the other day, at the Franklin Institute, was asked why he advised four feet of pressure over the sand. He replied that this was necessary to overcome the vacuum that took place in the sand-bed. I should like to know if any member of the Club can explain this. I have myself noticed, through the glass windows in my experimental filter-beds, a space between the top and bottom layers void of water, but I have not yet satisfied myself completely as to the cause of this empty space. Is it due to the air accumulating therein? or to a partial vacuum created by the fact that the drains allow the water to flow more easily than the filtering membrane at the surface allows it to pass through? Any information on this point might be very interesting.

In the concrete beds described by Mr. Ledoux I do not see any cement facing. In Paris reservoirs the concrete is laid on sand, and on the surface of the concrete is a good coating of cement with expanded metal. I suppose Mr. Ledoux counts on the puddle to prevent leakage, as concrete alone is not water-tight.

MR. LEDOUX.—Our pond affords several million gallons' capacity for sedimentation, but this is not of much account in times of high water. The concrete was covered with about ¾ of an inch of cement mortar. Filtered water was used with the apparatus for testing the rate of percolation through the sand.

An examination of the plans will show clearly how the filtration was maintained at a constant rate. The float has a fixed distance from circular weir opening, or orifice. As the sand becomes clogged the weir lowers, thus increasing the effective head, and hence the rate of percolation through the sand.

As far as the alum is concerned, I do not agree with Mr. Maignen. I believe that there is likely to be no bad effect, unless gross carelessness is permitted in the operation of the plant. At Lorraine, O., it was found that 1.75 grains per gallon increased the hardness of the water ½ of a degree, but that no alum appeared in the filtrate. At Pittsburg it was found that 1.5 grains of alum could be used safely with the Allegheny and Monongahela River waters. Both the Schuylkill and Delaware River waters contain enough mineral bases to thoroughly decompose the aluminum sulfate; so that I apprehend absolutely no danger from the use of alum if used in connection with filtration.

The water of Pickering Creek for the past twenty days has been in a fair condition so far as turbidity is concerned. Just now it is more than usually turbid. According to a method used by us, in which the water is graded from No. 1 for the clearest to No. 6 for the most turbid, the present condition of the creek would be about No. 3.

THE PRESIDENT.—Have you any data regarding the cost of maintenance?

MR. LEDOUX.—We have no data of value as yet as to the cost of operation of this plant. We have scraped one of the compartments once, requiring six men four hours for scraping. The washing required, approximately, 10½ volumes of water to one volume of sand.

It is our purpose later to have a series of bacteriological tests of the water made. However, the analysis of the raw creek-water shows it to be of good quality. Our criterion at present is to so filter the water as to produce an effluent of perfect transparency. It takes the water about two or three hours to make a good appearance. The washing works satisfactorily and shows that we had to pass it over six compartments. We had only four, but returned the sand over the last two. Six are about what are required. We use about twenty pounds' pressure, which gives good results, using about 10.5 parts of water to one of sand. We would take off about ¾ of an inch of sand and would scrape the beds about once in twenty-eight days. I think this will be an average length of time, because the water has been of average quality during this period.

HENRY LEFFMANN.—The effect of alum, when used as an aid in the filtration of water, has been much disputed among experts, and it is very difficult to approximate the truth. I think that we may safely assume that small quantities,—say, not over one grain to the gallon,—used with waters of ordinary type, containing notable amounts of carbonates, will not seriously impair the sanitary value of the water, since the alum will be all decomposed, and aluminum hydroxid will be collected on the filter; and even if a small amount of it does pass into the effluent, there seems to be no reason to suppose it to be directly unwholesome. We can not doubt that alum or aluminum sulfate introduced in any quantity into water will increase the permanent hardness and the liability to form hard scale. The technical uses of the water are thereby affected, and this is a question which a city like Philadelphia must carefully consider. When the quantity of alum rises above a grain to the gallon, and especially when it reaches, as it often does in the practical management of mechanical filters, four or five grains per gallon, the wholesomeness of the water is liable to be affected, and such liberal use of alum should be discouraged.

MR. LEDOUX.—Dr. Leffmann's opinion would carry more weight if he had an opportunity to make actual tests of filter plants in use. As above stated, the experiments, especially at Pittsburg, made by men who are evidently prejudiced to some extent in favor of slow sand filtration, show that alum can safely be used in amounts sufficient to clarify the water under all circumstances.

MR. MAIGNEN.—Nothing in the experiments of Louisville or Pittsburg diminishes the strength of our objections to alum or aluminum sulfate. On reading carefully the reports of Louisville on this subject, we will see, as Mr. Easby said at our last meeting, "that plain sand filters could not be used with the Ohio River water, on account of the fine clay which goes right through the bed of sand." Alum has been considered a necessity there; but once on this road, you may go farther than you intended; and thus it is that at Louisville the dose of alum has gone up sometimes as high as ten grains per gallon, which is very far from the hypothetic half-grain. I maintain that this chemical treatment, which is very costly, can be avoided, and better results obtained by filtration alone. If one filtration is not enough, let us make two, three, or more, if necessary; it will always be less costly than the chemical treatment, and will not, as water treated with alum, corrode the pipes, incrust boilers, and cause a great waste of soap and

coal. The cost of alum or aluminum sulfate is estimated at $3.50 per million gallons, at the rate of one grain per gallon.

The filtration plant we have installed at Cherbourg has now been running three and a half years. The death-rate has diminished at the rate of 6 per 1000, and the undertaker's business has had a setback. In France the privilege of burying the dead is put up at auction and awarded to the highest bidder. The company in Cherbourg, which had held the contract before the filtration plant was at work, has since failed because the burials have not come up in number to the expected standard.

THE PRESIDENT.—This is a very live topic and I hope the discussion will not end as yet. There is a question I would like to ask Mr. Trautwine. He is charged with not being decided in his purposes as to the proposed filter plant for the city. This discussion has brought out certain points which explain some of the difficulties under which he labors. For instance, the question of coagulant in its application to so extensive a plant as contemplated. Is it intended to use alum?

MR. TRAUTWINE.—The question of alum is a very important one in our case. Two methods of filtering are generally recognized and largely adopted. The one is slow sand filtration as in the filter described by Mr. Ledoux, and the other is the so-called mechanical filtration, using alum and filtering rapidly. Experiments made at Louisville, Ky., some fifteen years ago, showed that slow sand filtration was not well adapted to the Ohio River water—a fact which confirms the statement of Dr. A. C. Abbott, that slow sand filtration might not, under all circumstances, give results with the water of the Schuylkill River without good preparation for the prior sedimentation of the water. On the other hand, we are now told that the mechanical filter is objectionable on account of the alum used, but even the seventy tons of alum which it is said we should have to use daily are trifling in comparison with our daily pumpage. The question is, Would the injury caused by alum not be counteracted by the purification which it would produce?

In designing the system of filtration suggested (not recommended) in my report of September last, for using the major portions of the East Park, Queen Lane, Roxborough, and Belmont reservoirs as sedimentation basins, I designed a special sedimentation basin for the Roxborough supply. I wish to ask Mr. Ledoux the capacity of the clear-water basin at Berwyn.

MR. LEDOUX.—The clear-water basin holds 1,300,000 gallons. The use of ten grains of alum per gallon, as stated by Mr. Maignen, is entirely uncalled for under any circumstances. If a water were sufficiently turbid to require that amount, an engineer would certainly provide for preliminary sedimentation.

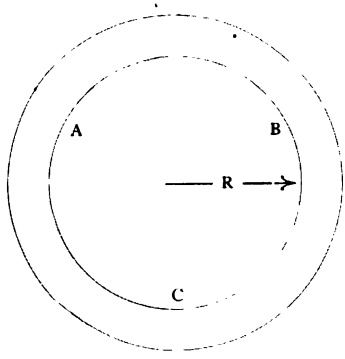
NOTES AND COMMUNICATIONS.

NOTE UPON THE STRENGTH OF TUBES TO RESIST INTERNAL PRESSURE.

L. Y. SCHERMERHORN.

Read by title February 18, 1899.

In Bartlett's "Analytical Mechanics" is found the following discussion of the thickness of a pipe, of any material, necessary to resist a given internal pressure. The subject is of interest in connection with recent statements concerning the pressure which certain tubes found in Keely's laboratory could resist:



"Let A B C be a section of pipe perpendicular to the axis, the inner surface of which is subjected to a pressure of p pounds on each superficial unit. Denote by R the radius of the interior circle, and by l the length of the pipe parallel to the axis; then will the surface pressed be measured by $2\pi\ R.\ l$; and the whole pressure by $2\pi\ R.\ l.\ p$.

"By virtue of the pressure, the pipe will stretch; its radius will become $R + d\ R$, the path described by the pressure will be $d\ R$, and its quantity of work in stretching will be:

$$2\pi\ R.\ l.\ p\ d\ R.$$

The interior circumference before the pressure was $2\pi\ R$, afterward $2\pi\ (R + d\ R)$, and the path described by resistance, $2\pi\ d\ R$. And if B denote the resistance which the material of the pipe is capable of opposing to a stretching force without losing its elasticity over each unit of section, t the thickness of the pipe, then, by the principle of the transmission of work, resistance = work, or:

$$2\pi.B.l.d\ R.t = 2\pi R.l.p.d\ R;\ \text{or}\ Bt = Rp;$$

whence,

$$t = \frac{Rp}{B}."$$

The tensile strength of copper is given as between 30,000 and 40,000 pounds per square inch. Assuming the elastic limit of copper as one-half its ultimate tensile strength, there would be obtained an elastic limit of 15,000 pounds per square inch, from the lower value of tensile strength above given. With this value of 15,000 pounds per square inch, a tube $\frac{1}{10}$ of an inch internal diameter, with an internal

pressure of 20,000 pounds per square inch, would be strained to its elastic limit, when its thickness, $t = \frac{\frac{1}{10} \times 20{,}000}{15{,}000} = \frac{1}{15}$ of an inch. Under these dimensions such a tube would have an external diameter of 0.233 of an inch.

With the thickness of tube, and pressure given, any known medium, for transmitting such pressures would probably rapidly pass through the pores of the material constituting the tube.

The foregoing discussion is only applicable to thin cylinders, and does not apply to thick cylinders, in which the thickness of the walls causes the interior stress to be greatly in excess of the exterior stress. Professor Barlow, in "Engineering," January 4, 1884, states: "In a homogeneous cylinder, if the metal is highly incompressible, the tension on every concentric layer, caused by internal pressure, varies inversely as the square of its distance from the center."

Mr. Carl Hering has called attention to the interesting fact, in the formula $Bt = Rp$, that when R, the interior radius of the tube, equals t, the thickness of the tube, then the formula reduces to $B = p$; or a tube whose thickness is equal to its inner radius will stand a pressure equal to the elastic limit of the material. Mr. Hering further states that the copper tubes, exhibited at a recent meeting of the Club, had an inside diameter of almost exactly $\frac{1}{10}$ of an inch, and an outside diameter of almost exactly $\frac{2}{10}$ of an inch. The above formula would indicate that such tubes would bear 15,000 pounds pressure per square inch.

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SOME PROBLEMS IN TELEPHONE ENGINEERING.*

THEODORE SPENCER.

Read March 4, 1899.

IN this paper an attempt will be made to briefly outline the general system of telephone lines as they are now arranged to give service; to discuss one or two of the more prominent of the details to which special attention must be given in arranging circuits, and then to state in a general way the problem of telephone engineering as it appears at the present time, together with an indication of some possible methods of solving some of the difficulties.

TYPICAL TELEPHONE SYSTEM.

The term "telephone exchange" is used technically to indicate the telephone system in a certain area. Thus, a corporation may be equipped with a telephone exchange in communication with the exchange that gives service to a large city. The term "central office" is used in a manner entirely analogous to the term "central station" in power work. In the case of the city of Philadelphia, for instance, the telephone exchange at the present time consists of eleven central offices in different parts of the city. The lines to the sub-

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scribers' stations in the districts served by each central office are carried to that office; each central office is connected directly or indirectly to every other central office by trunk lines.

The diagram shown in figure 1 indicates this condition in a general way. Each large office has a double-track system of trunk lines to each other large office. The smaller offices have trunk lines to the nearest large offices. The branch exchange is equipped with trunk lines to the nearest central office.

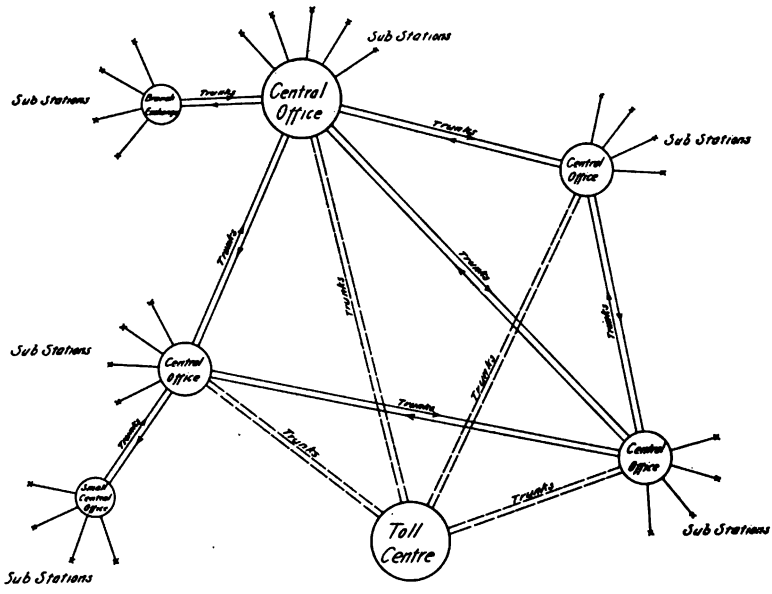


FIG. 1.—SCHEME OF TELEPHONE TRUNK LINE.

In telephone practice the terminology of railroads has been borrowed directly. There seems to be a sufficient similarity between the method of handling a freight package and a telephone call to justify this. So a "trunk line" is a circuit connecting two telephone centers; the "calls" are the "traffic handled" over a circuit, and a "double-track" system is one where any one line is used in one direction only. It is interesting to compare the diagram showing a telephone system in outline with one showing a typical railroad. The similarity to a diagram of the motor nervous system is even more striking.

At the present time a telephone exchange consists of two distinct but closely related systems:

First, service wires to subscribers' stations and trunk lines between central offices for use in actual talking. This may be called the "talking system."

Second, associated apparatus and circuits for use in signaling. This may be termed the "signaling system."

To give satisfactory results, a talking system of proper design is primarily essential, but telephone service can not be given on such a talking system unless the associated signaling system is reasonably complete. Without further considering the design of the talking system at present, the signaling system will be outlined. The method of operating telephones at present in use is by furnishing current for signaling and for energizing transmitters for talking from storage batteries at the central offices. The signaling system is operated on the same wires that are used for talking, and employs substantially direct or duplex telegraph methods; thus, a subscriber in lifting the telephone from the hook operates an automatic telegraph key, closing the circuit and giving a signal at the central office. These signals are received on relays; the relays operate some form of visual indicator. The indicators are usually miniature incandescent lamps, although in many cases electromagnetic signals are still employed. Audible signals, which may be spoken words or sounds given on the line by automatic apparatus, are used for signaling to the operators and between operators. Information as to whether a line is in use, for instance, is given to the operator by a single click heard in the head telephone on attempting to complete the connection; information that the line is in trouble is given by a low note heard under the same conditions; information that the line is held for a connection to some distant point may be given by a note at a different pitch. In the same manner interrupted flashes on the lamp signals may give information of almost unlimited detail to the operators. These audible and visual signals are given automatically by properly arranged commutators.

It will indicate more clearly the arrangement of a telephone exchange if one call is traced through to the final disconnection. A typical call would be as follows: The subscriber, by lifting the telephone off the hook, lights a miniature lamp in front of an operator;

SWITCH-ROOM OF MAIN TELEPHONE OFFICE, TOKIO, JAPAN.

this operator inserts a plug in a jack near the lamp and cuts in circuit with the subscriber, asking "Number?" On receipt of the number, the operator, by selecting the proper one of a number of push-buttons appearing in front of her, cuts in on a circuit to the trunk line operator at the central office, where the line of the subscriber terminates. The first, or the "subscriber," operator then repeats to the trunk operator the number of the line desired. The trunk operator answers by designating the number of the trunk line on which the connection is to be completed and by connecting that trunk line with the line called. A ringing key is then depressed by the trunk operator. When the called subscriber answers, a supervisory lamp in front of the subscriber operator indicates that fact. When one or both subscribers return the telephones to the hook, another signal is received on the supervisory lamps, and the finish of the conversation is indicated to the subscriber operator. When that operator disconnects, automatic indication is given to the trunk operator to also disconnect.

In each central office all the lines connected are made available in front of each operator—that is, the switchboard is a multiple one, each line being available at a number of places on the switchboard. The method of signaling to operators that the line is in use at some other point on the switchboard is by means of the audible tests referred to.

The present telephone exchange, then, consists of a number of central offices connected by trunk lines; each central office is equipped with multiple switchboards and with power plants for furnishing power to energize transmitters at subscribers' stations. Associated with this talking system is the automatic signaling system from subscribers' stations to central offices and between central offices, the signals being operated from the same power plant that is used to energize transmitters. The successful application of this system of signaling has involved the use of complex signaling circuits and the development of a mass of intricate and delicate apparatus. It would be impossible to explain the circuits or apparatus in detail without devoting far more time than is at my disposal this evening.

Toll System.

So far the telephone network has been viewed from a standpoint of local service only. For communication between distant points, the different exchanges throughout the country are connected by toll or long line systems.

Referring again to figure 1, it will be seen that one office is marked as a toll center. At that point the long lines, on which a special toll is charged, are centered in a suitable switchboard. By a complicated system of operating the ticket covering the connection between a sub-

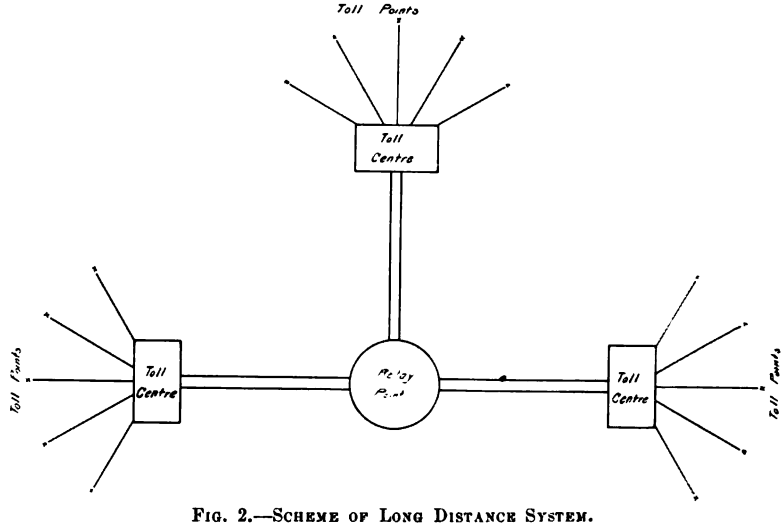


Fig. 2.—Scheme of Long Distance System.

scriber's station and any distant point is written at this toll center and not at the central office where the call originated. The connection is supervised and completed by operators at these toll centers.

Figure 2 shows the outline of the long line system. A connection between two subscribers in different cities is established by connecting the lines of the subscribers to the adjacent toll centers and then establishing conversation over the long line by proper method of signaling between these centers. In many cases it is necessary to pass the long lines through relay points, where they may be broken up into sections, so that the number of lines in each section may be varied to correspond

to the varying amount of business in that section. This is indicated on the diagram. These two diagrams,—figure 1 and figure 2,—if examined with the idea that telephone service requires two systems, one for talking and one for signaling, and that these must be arranged to work economically together, will give a general indication of the typical arrangement of lines that is necessary to give telephone service.

"Balance and Efficiency" in the Talking System.

With this somewhat vague outline of telephone exchange and of the signaling system it will be interesting to consider one or two of the difficulties met in designing a proper talking system.

The extreme sensitiveness of the telephone receiver makes a telephone system possible, and, at the same time, brings in some of the gravest difficulties in making that system satisfactorily operative. It has been calculated that the telephone will respond to $6 \times 10 \div 13$ amperes, or $\frac{6}{10000000000}$ of a milliampere. One foot-pound of energy applied to a telephone receiver with no loss in conversion would produce a continuous audible sound for over three thousand years. These figures can be taken to indicate the extremely minute force that will cause sounds in a telephone receiver.

All electric circuits are subject to inductive disturbances. These disturbances can be prevented by so arranging each circuit that the sides of the circuit are subjected to equal exposure. It has been determined by experiment that disturbance caused by static induction on telephone lines has a magnitude, in general, of about twenty times the disturbance of electromagnetic induction. It is also found by experiment that, if one inch of each of two telephone circuits equipped with what may be called standard apparatus are parallel at a distance of $\frac{1}{16}$ of an inch, and there is no confusion due to the presence of the other side of the circuits, conversation on one circuit can be clearly heard by induction on the other. This fact makes it almost impossible to satisfactorily balance a telephone circuit with respect to single wire. Two metallic circuits can be made inductively independent by twisting both wires in each circuit. The recent introduction of high potential alternating transmission in power practice has introduced an additional disturbing source that must be cared for in balancing telephone lines.

The extreme sensitiveness of the telephone, then, makes it impera-

tive to accurately "balance" the circuits used. Each side of each circuit must be equally exposed to every source of disturbance. The corresponding sections of each side must have the same resistance and insulation, must be raised to the same potential by displacement currents from a disturbing source, and must be identically affected by electromagnetic changes. The continually increasing use of electricity for light and power, and the increasing distances over which telephone service is commercially used, both make a more and more perfect balance necessary.

With the present apparatus, the power that would light an ordinary incandescent lamp for one hour would operate the average telephone station for about one month. This power, though small, is enormous when compared to the probable current in the telephone receiver when the intervening line is 1000 miles in length. The result is that the use of the term "efficient transmission" in telephone practice merely means that conversation can be carried on. A line is commercially efficient when the average user can satisfactorily talk over it. The word efficiency is used entirely independent of what particular fraction of one per cent. of the transmitted power is obtained at the receiving end. The result of this extreme difference in the amount of energy delivered to the wire and that received is that no rational formula for transmission on telephone currents has been deduced. Telephone engineering, so far as the proper size of the wire and arrangement of circuits is concerned, is based largely on empiric formula, and this is in spite of the fact that possibly more effort has been made by mathematicians and physicists to obtain proper rational formula for telephone transmission than has been the case in any other branch of applied electricity. Aside from the more technical questions of effective handling of apparatus and the design of circuits and apparatus, the question of balance and static loss in transmission is the most important. The so-called telephone period, or period of alternation that would represent the complicated combination of alternating currents that compose telephone current, may be considered to be about 1200 complete cycles a second. When the effect of capacity on the power-circuit frequencies of thirty and forty complete cycles a second is considered, its enormous effect on telephone currents can be understood.

Object of Telephone Service.

One of the most important questions to decide in speculating on the future of telephone work is the definition of the object to be obtained. It can be defined by saying that the problem before the telephone engineer is to devise apparatus by which any person in the world can speak to any other person at a moment's notice. At the present time it would be possible to construct a talking circuit on

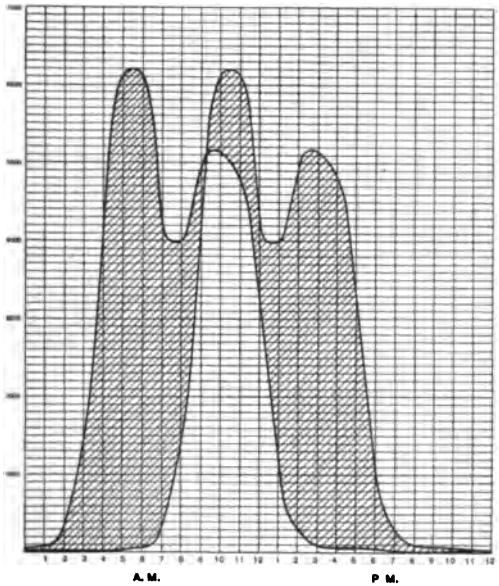


Fig. 3.—Comparison of London and New York Twenty-four Hours' Load-curves.

land several thousand miles long, provided sufficient copper were used. The transoceanic talking cable seems at the present time impossible, but will probably be possible in a few years. There is no limitation, apparently, on the ultimate distance of telephone communication. Suppose a telephone circuit in operative condition between London and New York, with five hours' difference in time—the London business day is closing as the New York day begins: would there be enough use for a telephone under these conditions to make it commercially possible? An examination of the diagram on figure 3 shows that the

use of it would be forced. There is, then, a limitation in the commercial possibility of the use of a telephone between points of different longitude. This limit is the difference in time. Figure 4 shows the San Francisco telephone day and the New York day compared. The conditions of industrial development would seem to confine the telephone largely to the temperate zone. It is difficult to imagine that any telephone circuit from New York to Buenos Ayres would be used. The ground, then, is limited, so far as America is concerned, to the

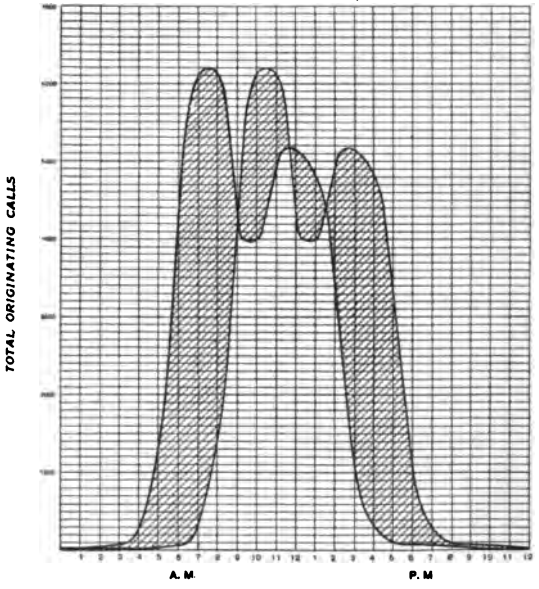


FIG. 4.—COMPARISON OF THE NEW YORK AND SAN FRANCISCO TWENTY-FOUR HOURS' LOAD-CURVES.

United States, with parts of Canada and Mexico included. The problem before the engineer at present may, then, be stated in this way: A plant and organization must be devised and operated so that any person in the United States may, at a few moments' notice, talk to any other person in the United States.

USE OF SERVICE.

Considering, then, that the present arrangement of central office and automatic signaling is fairly satisfactory and can be almost indefinitely

enlarged and modified to meet future conditions, and assuming that the difficulties introduced by the sensitiveness of the telephone can be removed by proper balancing of the line, the questions that are to be solved in order that satisfactory telephone service may be given become of a more general character.

Figure 5 shows the load curve at one of the central offices in this city. It will be seen from this that the maximum point is reached in the morning, that there is a decided drop at noon, and that between

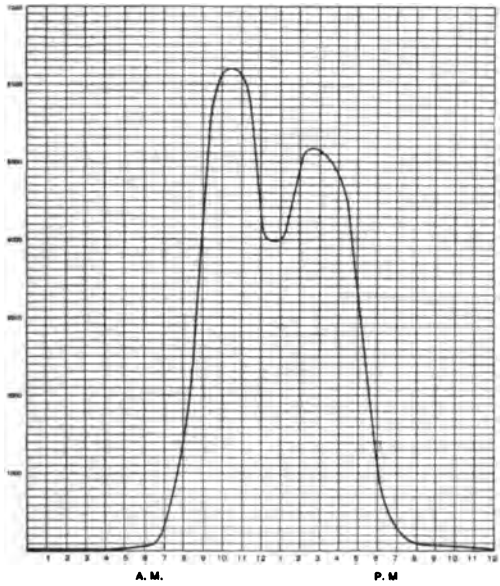


FIG. 5.—TWENTY-FOUR HOURS' LOAD-CURVE AT A PHILADELPHIA CENTRAL OFFICE.

the hours of five in the evening and nine in the morning there is comparatively little call for telephone service. When a customer orders coal from the dealer by the ton, or power from the power company by the kilowatt, it is easy with proper resources to supply almost an unlimited demand on the part of the customer. In telephone service there is a complication. The use of the line is not controlled by the subscriber for outward business; it is used by others for inward calls. In one telephone conversation two lines are used. If a subscriber calls for a number and fails to be connected because

the line is already in use and is reported busy, the telephone service has failed. The proposition to the subscriber whose line is busy that he incur additional expense in order that other people may talk to him on the telephone is in many cases a difficult one to establish.

It is an old simile to compare a telephone line to a door. The comparison is a reasonably exact one: both permit the entrance of business, and consequently profits, to the telephone subscriber. Under present conditions a large part of the daily business of the city is transacted on the telephone. Would it be wise for a business man to restrict his trade by forcing all visitors to pass through a single narrow door that was constantly in use by persons passing in the opposite direction? And is it wise to insist that incoming orders and information shall be forced through on one telephone line that is possibly already overcrowded with outgoing calls?

These are questions that must be answered rightly or telephone service is still far from ideal. Perhaps the question may be solved by a suitable method of metering telephone service. The method of metering is one of the questions of importance now pressing for solution.

Figure 6 shows in a general way the relation between the number of good calls that are made over a line in and out a day and the number of times that the line is reported busy a day. Three curves are shown, corresponding roughly to three different classes of business. The steeper curve shows the relation in the case of a stock broker's line, where business is compressed into a few hours of the day; the middle line may be taken as showing the average use, while the lower curve shows the relation between good calls and busy reports for business houses where the actual working day is ten or twelve hours. A line is in use for two minutes on the average for each conversation; the possible maximum of calls is, therefore, about thirty an hour. With fifteen calls an hour on a line, the probability is that a busy report would be given on a call for that line once out of two times, as the line is in use thirty minutes out of each hour. One of the hardest problems to be solved is the best way to handle these busy reports.

Particular Person Service.

In the preceding paragraphs I have endeavored to outline the plant that is at the present time considered most suitable for reaching the

result necessary. The proper organization to operate such a plant introduces problems not materially different from those met in organizing any large business. I have said that the problem is to make arrangements which will permit of any person in the United States speaking to any other person in the United States upon reasonable

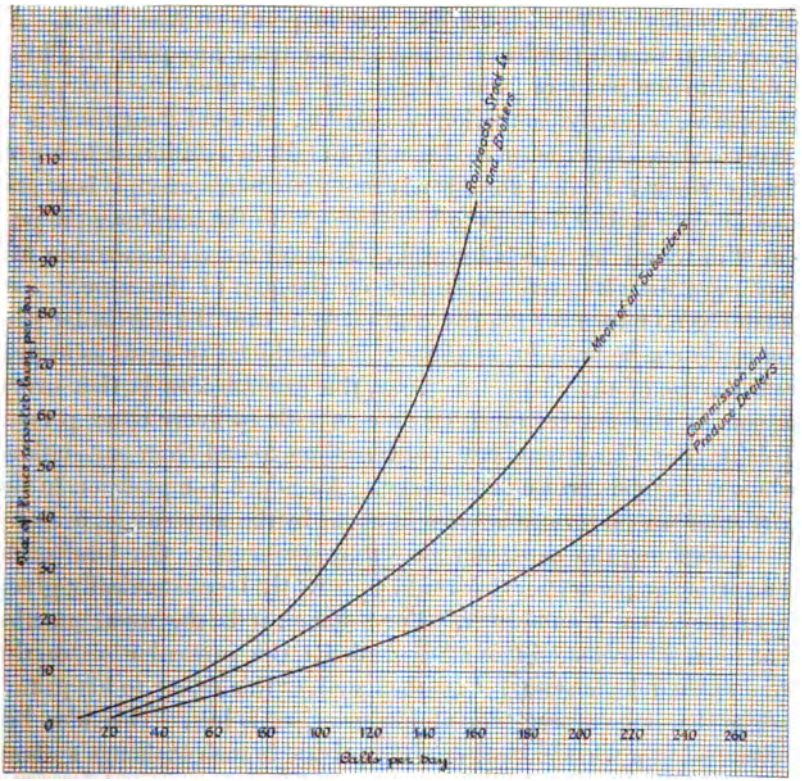


FIG. 6.—COMPARISON OF "GOOD" CALLS AND "BUSY" REPORTS IN TWENTY-FOUR HOURS.

notice. This brings up the question of what may be called "particular person service." Does a subscriber in general wish to talk to some particular person at some house or office, or simply to any one at that office? Probably about seventy-five per cent. of the local business transmitted on the telephone is to any one at an office. As the distance increases, the percentage of business that is

for some particular person increases to almost one hundred per cent. The particular person service as against direct number service is analogous to the old practice of railroads in this country and the present one. By furnishing cab service, the railroads give a convenience analogous to particular person service in telephone work. A few years ago the Pennsylvania Railroad Company operated trains between certain points in Philadelphia and certain points in New York. At the present time it furnishes transportation from any point in Philadelphia to any point in New York. In many cases the Telephone Company gives only connection to a station. One of the questions to be decided is, Does the subscriber wish to talk to a station or to a particular person? If the subscriber is connected to a station, it is at any time an easy matter for him to have brought to the telephone the person with whom he wishes to speak. If, however, a considerable toll is charged for a connection, the risk on the part of the subscriber of obtaining no return for the payment made in case the particular person could not be brought to the station would be so great as to prevent the use of the telephone. Also, the general idea is that every person in the country must be able to talk to every other person. This implies a large number of conversations to and from pay-stations where messenger service is necessary. An added complication in the particular person service is brought about by the necessity of, in many cases, obtaining the particular person by messenger. On local calls, the particular person service could apparently be economically given by employees of a subscriber. For instance, it is the usual practice that some subordinate in an office shall get the particular person desired to the telephone and shall then deliver this report to his principal, so that none of the time of his principal is lost. This idea has developed into what is known as the private branch exchange system, where an operator employed by the subscriber is equipped with special apparatus and obtains particular persons before delivering the call to the originator.

One of the incidental developments of this particular side of the telephone service seems to be an exaggeration of personality. The conversation over the telephone is in general unsatisfactory, especially so on important affairs, unless there is a personal acquaintance between the persons talking. It has often been said that the use of the long distance telephone removed the necessity of travel-

ing to a large extent, but not entirely. While it was unnecessary to travel for the transaction of immediate business, it is necessary to frequently visit correspondents, in order that the personal acquaintance might be renewed, the personal acquaintance being a necessary preliminary to the transaction of important business on the telephone.

Two of the interesting questions now before the telephone engineer are:

First, Where is the balancing point between the demands of the subscriber and the economical possibilities of telephone service in relation to particular person service.

Second, How can a just and economical system be devised that will prevent an undue number of "busy" reports?

These may be considered as some of the general problems, aside from the more technical ones of improved design and operation of circuits and apparatus.

When the telephone is viewed from a broad standpoint, the possibilities of a mechanical telephone exchange are seen to be limited. To devise an automatic mechanical telephone system—one where the subscriber, by pushing a series of buttons at his station, completed the connection—would be as difficult to arrange as to place a mechanical attachment on the phonograph that would operate the typewriter. There may be great possibilities of improvement in typewriting machines; there doubtless are greater possibilities of improvement in telephone apparatus; but in either case it is improbable that the operator will ever be eliminated, though the personality of the operator may, and all recent modifications in telephone apparatus have been made with that in view.

In conclusion, it must be borne in mind that the telephone apparatus and circuits now used originated in this country and are copied throughout the world. At the present time there is a rapid enlargement of the telephone system in London in progress. For this work the central office switchboards are supplied by an American manufacturer. The underground cables are supplied by American manufacturers. Much of the conduit used is manufactured almost within the limits of this city. In other words, all of the important equipment is American. It has not yet been possible to install in this country apparatus that was not antiquated before it could be used. This will

indicate how steady and how rapid the improvement in telephone methods and in the design of apparatus has been.

While it is always proper to criticize the shortcoming of any service, in criticizing the service given by the telephone system the extraordinary usefulness and rapid development of the apparatus and plant must be considered. Aside from the questions like the general ones of particular person service, improvement in this, as in other industrial undertakings, can only be reached by steady and patient development in the detail of apparatus and operating.

CEMENT AND CEMENT TESTING.

ROBERT W. LESLEY.

Read December 17, 1898.

AMONG the materials for construction which enter very largely into all the important work in the country is cement, and as the modern tendency in all the construction materials is toward accuracy, system, and definiteness, the testing of cement has, like the testing of steel, iron, and brick, become an important factor with the architect and with the engineer in charge of the erection of large buildings or the construction of large public work. There is, however, a very material difference in the testing of cement and the testing of other materials of construction—a difference which, perhaps, enough consideration has not been given to by those requiring the tests, or by the engineering community generally. This great difference lies in the fact that all the other material of construction—from the sand that goes into the mortar to the ironwork that forms the supports for carrying the roof—can in every case be tested in its original condition as it comes there as a product of nature herself, or as the most finished product of the most successfully conducted manufacturing enterprises, such as the steel- and iron-works of this country. While it is possible, therefore, for the architect or the engineer to send his expert to the sand-bank and have a test of the sand made and accept or refuse it upon its chemical or mechanical conditions as they actually exist, it is also possible for him to send to the steel- or iron-works whence the material is to come, and to test the material that he is to put in the buildings or bridges, in the conditions that it is to be actually used in the building, and in the condition in which it has received the last touch of its manufacturing manipulation. Therefore, the testing of these materials may take place with perfect fairness to the producer and to the consumer, in either the place where nature has produced them,—in the sand-pit for the sand, in the quarry for the stone,—or in the condition of finished manufacture in the iron-works or in the steel-works. And, further, they may also be tested in their finished condition as

delivered upon the work where they are to be used. In every case, in all these materials, no act of the engineer, no act of the producer, no act of the consumer can in any way alter either the raw product or the finished product which is submitted at the place of its production or the condition in which it is delivered at the place of its use. For this reason, in these materials, which broadly embrace every article used in large construction, there can be no question as to the testing or as to the condition of the material to be tested.

With cement, however, an entirely different condition exists. No engineer and no architect would accept a barrel of cement at the mill upon tests made of that material in powder alone. If the only test prescribed was the test of its specific gravity,—the tests of its weight per cubic foot, the tests of its fineness, the tests of its chemical analysis,—it would be possible for the cement manufacturer and for the engineer or architect to apply the same rules of testing to cement as are applied to the testing of all the other materials above enumerated. These tests would be simple mechanical ones, to be made without discrimination at the place of production or the place of use. These tests could all be determined by the scientist or the layman, by the manufacturer, the architect, or the engineer. They are all tests of the material as it is made, in the condition in which it is produced, and they could be made at any point from the place of manufacture to the place of consumption. In the testing of cement, however, as prescribed, and properly so, by all specifications, a further element is introduced, and that element is the testing of the material for tensile or for compression strains. It can be readily seen and understood that the powder alone can not be tested in this way; for this reason briquettes are made of cement with water, and these are put in testing machines for the purpose of being broken by tension or crushed by compression. The making of these briquettes involves an operation that must be performed after the ultimate completion of the manufactured product, and involves a process of treating that manufactured product by either the engineer or the testing expert to obtain results to meet the required specification. Now, this testing is the crucial point in all the issues that arise in the use of cement all over the civilized world. On the one hand, the manufacturer produces his finished product. He tests that finished product, mixing it with water and sand,—makes his briquettes,—breaks his briquettes, and has ready

for shipment a product which, according to his results, meets the requirements of the specification. This identical material loaded in a closed car, sealed with the seal of a railroad company, goes to the destination of its use, and a new person, possibly unfamiliar with this particular cement, possibly unfamiliar with methods of testing, and possibly unfamiliar with all the elements that enter into the handling of a material like cement, proceeds in his own way to make tests of this material. The briquettes that he produces are the manufactured product not of the manufacturer, but of the tester on the work. There is a new manufactured product now to be tested. This manufactured product is the cement which leaves the mill, the water which is used by the tester, the sand which is used by the tester, and the personal equation of the tester, plus the personal equation of his laboratory in combination.

Now, the purpose of my paper to-night is to give you in a brief way, from the cement manufacturer's point of view, after some twenty-five years of experience, and to give you also, possibly, from the engineer's point of view, as well after many years' association with the profession, some slight idea of the various specifications that have to be met with in the use of cement, of the difficulties in the testing of cement, and of the machinery for testing cement, with some description of the various leading laboratories in this country and in Europe for this purpose.

Differences in Specifications.

The first question in the use of cement, as well as the first question in the manufacture of cement, that confronts either the manufacturer or the engineer, is, What is the specification for the article that is to be used? Testing this from the engineer's standpoint, he will be guided by the character of the work he has to do, by the requirements in time, by the element of permanence, and by the experience of other engineers who have done similar work. This specification he will make according to his best lights, with all fairness and with all candor. That specification is put in print and the manufacturer in turn is confronted with its requirements. He may be making a cement of one character and for reasons known to him as a manufacturer, and resulting from his experience, he may consider that the cement made to meet the specification submitted may be a perfectly safe, satisfac-

tory, and proper cement for the work in which it is to be used. He may, on the other hand, discover that the specification contains elements which to his mind, in view of the conditions under which the material is to be used, would involve the manufacture of a cement that would be dangerous, and the failure of which, while it would injure the engineer, would also seriously injure the reputation of the cement manufacturer and ruin his business. In some cases these matters can be reconciled between the manufacturer and the engineer; in other cases the manufacturer is forced to decline to supply cement, or, if led away by the hope of gain rather than the hope for the up-building of a reputation, he undertakes to make the cement, and throws the blame on the engineer.

Now, in the past six or eight years, I have been gathering specifications and filing them away carefully, and very recently I took the trouble to put them together, classify them according to the various grades of work, to average them according to their varying character, and to make a general summary of all the specifications up to a very recent period that have come to me in the course of a rather extended experience. These specifications show the variations to which the manufacturer must fit his cement, and show the difficulties under which he labors, and the necessity of some thorough understanding as to the methods under which the cement is to be tested.

PORTLAND CEMENT.

TESTS FOR FINENESS.

RESIDUE ON SIEVES OF VARIOUS SIZES.

Russia.—Twenty per cent. on a 5800-mesh sieve (Government specification).

Belgium.—Fifteen per cent. on a 5800-mesh sieve (Genie Belge).

Germany.—Ten per cent. on a 5800-mesh sieve (Rules Prussian-German Society).

Switzerland.—Fifteen per cent. on a 5800-mesh sieve (Report Tetmajer, Zürich).

France.—No fineness specification (Cahier des charges, Ponts et Chaussées ; or in Government Commission Report).

France.—Five per cent. on a 5800-mesh sieve (recommended by Le Chatelier and Candlot).

England.—Eight per cent. on a 2500-mesh sieve (recommended by H. Faija, World's Fair Congress, August 2, 1893).

United States.—Recommendation American Society of Civil Engineers, June 27, 1893, says: "Cements of better grades are ground so fine that only from 5 per cent. to 10 per cent. is rejected on a sieve of 2500 meshes per square inch."

Under this recommendation of American Society of Civil Engineers are the following specifications in this country :

UNITED STATES GOVERNMENT ENGINEERS.

Hawkins Point, Md., United States Engineers, 1896 : 95 per cent. on a 2500-mesh sieve.

Kentucky River, Lock No. 7, United States Engineers, 1896 : 98 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Cumberland River Improvement, United States Engineers, 1897 : 87 per cent. on a 10,000-mesh sieve.

Sandy Hook, United States Engineers, 1896 : 90 per cent. on a 2500-mesh sieve.

Dutch Island, R. I., 95 per cent. on a 2500-mesh sieve ; 77 per cent. on a 10,000-mesh sieve.

Fort Monroe, United States Engineers, 1897 : 95 per cent. on a 4000-mesh sieve.

Wetumpka, Ala., United States Engineers, 1894 : 95 per cent. on a 2500-mesh sieve ; 90 per cent. on a 5476-mesh sieve.

Fort Pickens, Fla., United States Engineers, 1897 : 96 per cent. on a 2500-mesh sieve.

Pensacola, Fla., United States Engineers, 1893 : 100 per cent. on a 2500-mesh sieve ; 90 per cent. on a 5476-mesh sieve.

Fort Washington, Md., United States Engineers, 1897 : 95 per cent. on a 2500-mesh sieve.

Mouth Cape Fear River, N. C.: 99 per cent. on a 2500-mesh sieve ; 90 per cent. on a 10,000-mesh sieve ; 70 per cent. on a 40,000-mesh sieve.

Great Gull Island, United States Engineers, 1897 : 95 per cent. on a 2500-mesh sieve.

United States Engineers, Key West, Fla.: 96 per cent. on a 2500-mesh sieve ; 90 per cent. on a 10,000-mesh sieve ; 70 per cent. on a 40,000-mesh sieve.

United States Engineers, West Point, N. Y., 1896 : 95 per cent. on a 2500-mesh sieve ; 85 per cent. on a 10,000-mesh sieve.

Santa Rosa Island, Fla., United States Engineers, August, 1897 : 96 per cent. on a 2500-mesh sieve.

Monongahela River Locks, United States Engineers, 1897 : 98 per cent. on a 2500-mesh sieve ; 87 per cent. on a 10,000-mesh sieve.

Coosa River, United States Engineers, 1894: 95 per cent. on a 2500-mesh sieve ; 90 per cent. on a 5476-mesh sieve.

Green River Improvement, United States Engineers, 1897 : 99 per cent. on a 2500-mesh sieve ; 87 per cent. on a 10,000-mesh sieve.

United States Engineer's Office, Washington, D. C., Major E. L. B. Davis, August 14, 1895 : 95 per cent. on a 4000-mesh sieve.

United States Engineer's Office, Detroit, Mich., Colonel O. M. Poe, September 28, 1895 : 96 per cent. on a 2500-mesh sieve ; 75 per cent. on a 14,400-mesh sieve.

United States Engineer's Office, Duluth, Minn., Major E. B. Sears, January 28, 1895: 75 per cent. on a 10,000-mesh sieve.

United States Engineer's Office, Chattanooga, Tenn., Captain Daniel C. Kingman, July 1, 1895 : 87 per cent. on a 10,000-mesh sieve.

Rock Island Arsenal, Rock Island, Ill., Colonel A. R. Buffington, July 22, 1896 : 95 per cent. on a 2500-mesh sieve.

Portland Head, Me., United States Engineers, 1896 : 95 per cent. on a 2500-mesh sieve.

Marquette, Mich., Breakwater, United States Engineers, 1895 : 75 per cent. on a 10,000-mesh sieve.

Newport and New London, United States Engineers, 1897 : 95 per cent. on a 2500-mesh sieve ; 77 per cent. on a 10,000-mesh sieve.

Marietta, Ohio, United States Engineers, 1896 : 90 per cent. on a 2500-mesh sieve.

Fort Preble, Me., United States Engineers, 1896 : 95 per cent. on a 2500-mesh sieve.

Galveston, Tex., United States Engineers, 1896 : 95 per cent. on a 2500-mesh sieve.

Tybee Island, Ga., United States Engineers, 1896 : 90 per cent. on a 10,000-mesh sieve.

Sault Ste. Marie, United States Engineers : 95 per cent. on a 2500-mesh sieve.

St. Mary's Falls Canal, United States Engineers, 1895 : 75 per cent. on a 14,400-mesh sieve ; 96 per cent. on a 2500-mesh sieve.

Sullivan Island, S. C. : 85 per cent. on a 10,000-mesh sieve.

Sheridan's Point, Va. : 95 per cent. on a 2500-mesh sieve.

Portsmouth, N. H. : 95 per cent. on a 2500-mesh sieve.

Average of 35 : 95½ per cent. on a 2500-mesh sieve ; 84 per cent. on a 10,000-mesh sieve ; 70 per cent. on a 40,000-mesh sieve.

United States Lighthouse Engineers.

Office United States Lighthouse Engineers, Fifth District, Baltimore, Captain E. Bergland, August 22, 1894 : 95 per cent. on a 2500-mesh sieve.

Narragansett Bay, United States Lighthouse Engineers : 95 per cent. on a 2500-mesh sieve.

Average : 95 per cent. on a 2500-mesh sieve.

United States Engineers, Navy Department.

United States Navy Yard, Mare Island, Cal. : Captain H. L. Harrison, December 27, 1895 : 90 per cent. on a 6400-mesh sieve.

United States Navy Yard, Norfolk, Va. : H. F. R. Harris, Paymaster, October 30, 1896 : 97 per cent. on a 3600-mesh sieve.

Norfolk, Va., Navy Department, 1895 : 90 per cent. on a 6400-mesh sieve.

United States Navy Yard, Washington, D. C. : Commodore J. A. Howell, December 24, 1895 : 90 per cent. on a 6400-mesh sieve.

United States Navy Department, Washington Navy Yard, 1895 : 90 per cent. on a 6400-mesh sieve.

Average : 90 per cent. on a 6400-mesh sieve ; 97 per cent. on a 3600-mesh sieve.

District of Columbia.

United States Engineers, Washington, D. C., Aqueduct, 1896 : 95 per cent. on a 2500-mesh sieve.

United States Government, District of Columbia, 1897: 95 per cent. on a 2500-mesh sieve; 85 per cent. on a 10,000-mesh sieve.

United States Government, District of Columbia, 1894: 95 per cent. on a 2500-mesh sieve.

United States Government, District of Columbia, 1894: 85 per cent. on a 10,000-mesh sieve.

United States Government, Supervising Architect: No fineness specified.

Average: 95 per cent. on a 2500-mesh sieve; 85 per cent. on a 10,000-mesh sieve.

CITIES.

Easton, Pa., 1897: 85 per cent. on a 10,000-mesh sieve; 99 per cent. on a 2500-mesh sieve; 60 per cent. on a 40,000-mesh sieve.

Williamsport, Pa.: 97 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Wilmington, Del.: 94 per cent. on a 10,000-mesh sieve.

Waltham, Mass., 1895: 95 per cent. on a 2500-mesh sieve; 88 per cent. on a 5000-mesh sieve; 67 per cent. on a 14,400-mesh sieve.

New York Department of Docks, 1891: 90 per cent. on a 2500-mesh sieve.

Pittsburg Reservoir: 75 per cent. on a 40,000-mesh sieve; 95 per cent. on a 10,000-mesh sieve; 99 per cent. on a 2500-mesh sieve.

Wallabout Improvement, City of Brooklyn, 1896: 99 per cent. on a 2500-mesh sieve; 90 per cent. on a 10,000-mesh sieve; 70 per cent. on a 40,000-mesh sieve.

City of Baltimore: 90 per cent. on a 3000-mesh sieve.

City of Philadelphia: 99 per cent. on a 2500-mesh sieve; 90 per cent. on a 10,000-mesh sieve; 70 per cent. on a 40,000-mesh sieve.

Average: 97 per cent. on a 2500-mesh sieve; 89 per cent. on a 10,000-mesh sieve; 69 per cent. on a 40,000-mesh sieve.

RAILROADS.

Philadelphia and Reading: 97 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Columbus and Ninth Avenue Railroad, New York: 96 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Metropolitan Street Railway, New York: 96 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Metropolitan Street Railway, Washington, 1894: 97 per cent. on a 2500-mesh sieve.

New York Central Railroad: 97 per cent. on a 2500-mesh sieve.

Pennsylvania Railroad: 90 per cent. on a 2500-mesh sieve.

Average: 95½ per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

BRIDGES.

New East River Bridge: 90 per cent. on a 10,000-mesh sieve.

New York and Long Island Bridge (Corbin's): 97 per cent. on a 2500-mesh sieve; 80 per cent. on a 10,000-mesh sieve.

Catawissa Bridge, 1897: 90 per cent. on a 10,000-mesh sieve; 95 per cent. on a 2500-mesh sieve.

Willis Avenue Bridge, New York: 98 per cent. on a 2500-mesh sieve; 85 per cent. on a 10,000-mesh sieve.

Topeka Bridge, Kan.: 95 per cent. on a 10,000-mesh sieve.

Fourth Avenue Bridge, New York, New York Central Railroad: 97 per cent. on a 2500-mesh sieve.

Average: 97 per cent. on a 2500-mesh sieve; 88 per cent. on a 10,000-mesh sieve.

AQUEDUCTS, DAMS, ETC.

New Croton Aqueduct, 1896: 80 per cent. on a 10,000-mesh sieve.

Niagara Falls Tunnel: 80 per cent. on a 10,000-mesh sieve.

Average: 80 per cent. on a 10,000-mesh sieve.

MISCELLANEOUS.

Warren Scharf Paving Company: 90 per cent. on a 6400-mesh sieve.

AVERAGE.

Average 71 specifications: 96 per cent. on a 2500-mesh sieve; 85 per cent. on a 10,000-mesh sieve; 69 per cent. on a 40,000-mesh sieve.

Average European Government specifications: 88 per cent. on a 5800-mesh sieve; 92 per cent. on a 2500-mesh sieve.

TENSILE STRAIN.

NEAT TESTS.

	SEVEN DAYS. (Pounds.)	TWENTY-EIGHT DAYS. (Pounds.)
Norway,	455	568
France,	277	497 (Cahier Guillain.)
Russia,	297	(Russian public works.)
Belgium,	355	497 (Genie Belge.)
England,	350	550 (Faija) (Carey.)
Germany,	No neat requirements.	

American Society of Civil Engineers (250 to 550 pounds at seven days, 350 to 700 pounds at twenty-eight days) tests recommended.

Under these recommendations of American Society of Civil Engineers are the following American specifications:

UNITED STATES ENGINEERS.

	TWENTY-FOUR HOURS. (Pounds.)	SEVEN DAYS. (Pounds.)	TWENTY-EIGHT DAYS. (Pounds.)
Cumberland River Improvements, United States Engineers, 1897,		430	500
Sandy Hook, N. J., United States Engineers, 1896,		450	

	Twenty-four Hours. (Pounds.)	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
Hawkins Point, Md., United States Engineers, 1896,	. .	300	400
Green River Improvement, United States Engineers, 1897,	. .	430	500
Lock No. 7, Kentucky River, United States Engineers, 1896,	. .	350	. .
Tombigbee River, United States Engineers, 1897,	. .	400	. .
Fort Monroe, United States Engineers, 1897,	. .	450	700
Coosa River, United States Engineers, 1894,	. .	350	. .
Diamond Shoals, United States Engineers,	. .	375	. .
Sault Ste. Marie, United States Engineers,	. .	400	. .
St. Mary's Falls Canal, United States Engineers, 1895,	. .	400	. .
Newport and New London, United States Engineers, 1897,	. .	400	600
Marietta, Ohio, United States Engineers, 1896,	. .	350	. .
Lock No. 6, Nashville, Tenn., United States Engineers,	. .	430	500
Dutch Island, R. I.,	. .	400	600
Santa Rosa Island, Fla., United States Engineers, 1897,	. .	380	490
Portsmouth, N. H.,	. .	400	. .
United States Engineer's Office, Washington, D.C., Major E. L. B. Davis, August 14, 1895,	. .	450	700
United States Engineer's Office, Detroit, Mich., Colonel O. M. Poe, September 28, 1895,	. .	400	. .
United States Engineer's Office, Chattanooga, Tenn., Captain Daniel C. Kingman, July 1, 1895,	. .	430	500
United States Engineer's Office, Philadelphia, Pa., Major C. W. Raymond, July 21 and October 15, 1896,	. .	400	600
	. .	450	600
United States Engineer's Office, Newport, R. I., Major D. W. Lockwood, August 25, 1896,	. .	400	600
Rock Island Arsenal, Rock Island, Ill., Colonel A. R. Buffington, July 22, 1896,	. .	450	. .
United States Government Army Engineers, 1893,	. .	450	. .
United States Government Army Engineers, 1896,	. .	350	. .
Mouth Cape Fear River, N. C.,	. .	500	600
Sullivan's Island, S. C.,	. .	375	500
Sheridan's Point, Va.,	. .	375	. .
San Diego, Cal.,	. .	450	700
Fort Washington, Md., United States Engineers, 1897,	125	375	. .
Pensacola, Fla., United States Engineers, 1893,	. .	450	600

	Twenty-four Hours. (Pounds.)	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
Portland Head, Me., United States Engineers, 1896,	. .	380	. .
Fort Pickens, Pensacola, Fla., United States Engineers, 1897,	. .	380	490
Wetumpka, Ala., United States Engineers, 1894,	. .	350	500
Fort Preble, Me., United States Engineers, 1896,	150	380	. .
Galveston, Texas, United States Engineers, 1896,	. .	400	500
Finn's Point, N. J., United States Engineers, 1897,	. .	400	600
Great Gull Island, United States Engineers, 1897,	. .	. .	400
West Point, N.Y., United States Engineers, 1896,	125	400	500
Key West, Fla., United States Engineers,	125	400	500
Monongahela River Locks, United States Engineers, 1897,	. .	400	500
Average,	131	402	547
United States Lighthouse Engineers.			
United States Lighthouse Engineers,	. .	500	. .
Tompkinsville, S. I., United States Lighthouse Engineers, 1897,	. .	500	600
Narragansett Bay, Lighthouse Engineers,	. .	300	. .
United States Government Lighthouse Engineers, 1893,	. .	400	. .
United States Government Lighthouse Engineers, 1896,	. .	300	. .
Office United States Lighthouse Engineers, Fifth District, Baltimore, Md., Captain Erick Bergland, August 22, 1894,	. .	300	. .
Average,	. .	383	600
United States Navy Department Engineers.			
Navy Department, Norfolk, 1895,	. .	400	. .
United States Navy Department, Washington Navy Yard, 1895,	. .	400	. .
United States Navy Yard, Norfolk, Va., H. F. R. Harris, Paymaster, October 30, 1895,	. .	550	. .
United States Navy Yard, Washington, D. C., Commodore J. A. Howell, December 24, 1895,	. .	500	. .
Average,	. .	462	. .
Supervising Architect.			
United States Government,	. .	300	. .
United States Government, Supervising Architect, Savannah Post-office,	. .	350	. .
Average,	. .	325	. .

	Twenty-four Hours. (Pounds.)	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
District of Columbia.			
Washington, D. C., Aqueduct, United States Engineers, 1896,	. .	400	. .
United States Government, 1895,	. .	400	500
United States Government, 1896,	. .	375	500
United States Government, 1897,	. .	375	500
Average,	. .	387	500
Cities.			
Pittsburg Reservoir,	. .	500	600
City of Niagara, N. Y.,	125	300	400
Easton, Pa., 1897,	150	400	500
Williamsport, Pa.,	. .	300	. .
Wilmington, Del.,	200	400	. .
Waltham, Mass.,	. .	300	380
New York Dock Department, 1891,	. .	300	. .
Wallabout Improvement, Brooklyn, N. Y., United States Engineers, 1896,	150	400	600
Wallabout Improvement, United States Engineers, 1897,	. .	. .	600
City of Brooklyn,	. .	400	600
City of Baltimore,	. .	400	. .
Reading, Pa., 1896,	200	500	650
Reading, Pa., 1898,	125	350	450
City of Philadelphia,	175	500	600
Average,	161	388	538
Railroads.			
Philadelphia and Reading Railroad, 1891,	150	350	. .
Metropolitan Street Railway, Washington, 1894,	125	400	500
Metropolitan Railway, New York,	. .	300	. .
Pennsylvania Railroad Company,	100	303	450
New York Central Railroad,	100	300	500
Baltimore and Ohio Railroad,	. .	300	. .
Lehigh Valley Railroad,	. .	300	. .
Columbus and Ninth Avenues Railroad Co., New York,	100	300	. .
Average,	115	319	483
Aqueducts, Dams, Etc.			
Chicago Drainage Canal,	. .	400	. .
New York Aqueduct, Jerome Park Reservoir, Cornell Dam,	110	300	400
Niagara Falls Tunnel,	. .	300	400
Average,	110	333	400

BRIDGES.

	Twenty-four Hours. (Pounds.)	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
New East River Bridge,	. .	350	. .
Catawissa Bridge, Pennsylvania, 1897,	175	450	550
New York and Long Island Bridge (Corbin's),	100	303	. .
Fourth Avenue Bridge, New York,	100	300	500
Willis Avenue Bridge, New York,	100	225	400
Topeka, Kan., Bridge,	. .	400	. .
Lenox Avenue Bridge, New York, 1898,	. .	350	. .
New York City, Third Avenue Bridge,	. .	300	500
Average,	119	347	487

MISCELLANEOUS.

Warren Scharf Paving Company,	. .	350	500

AVERAGE.

Average of European Government specifications,	. .	347	528
Average of 91 American specifications,	134	384	528

THREE PARTS SAND TO ONE PART CEMENT.

EUROPEAN SPECIFICATIONS.

	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
Norway,	156	213
France,	113	213
Germany,	. .	227
Austria,	142	213
Russia,	71	113
Belgium,	. .	215
England,	113	213
Switzerland,	. .	227
Average,	119	204
American Society of Civil Engineers recommends	80–125	120–200

UNITED STATES ENGINEERS.

Cumberland River Improvement, United States Engineers, 1897,	120	180
Sandy Hook, N. J., United States Engineers, 1896,	125	200
Lock No. 7, Kentucky River, United States Engineers, 1896,	100	. .
Tombigbee River, United States Engineers, 1897,	125	200
Coosa River, United States Engineers, 1894,	90	. .
Green River Improvement, United States Engineers, 1897,	125	200
Sullivan Island, S. C.,	125	175
Dutch Island, R. I.,	125	200
West Point, N. Y., United States Engineers, 1896,	100	150
Monongahela Locks, United States Engineers, March, 1897,	125	200

	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
Monongahela Locks, United States Engineers, October, 1897,	125	175
Lock No. 6, Nashville, Tenn., United States Engineers,	120	180
United States Engineer's Office, Detroit, Mich., Colonel O. M. Poe, September 28, 1895,	125	200
United States Engineer's Office, Duluth, Minn., Major E. B. Sears, January 28, 1895,	125	200
United States Engineer's Office, Chattanooga, Tenn., Captain Daniel C. Kingman, July 1, 1895,	120	180
United States Engineer's Office, Philadelphia, Pa., Major C. W. Raymond, July 21 and October 15, 1896,	125	200
United States Engineer's Office, Newport, R. I., Major D. W. Lockwood, August 25, 1896,	125	200
Rock Island Arsenal, Ill.,	140	. .
Diamond Shoals, United States Engineers,	100	. .
Tybee Island, Ga., United States Engineers, 1896,	125	200
Sault Ste. Marie, United States Engineers,	125	. .
St. Mary's Falls Canal, United States Engineers, 1895,	125	200
Marquette, Mich., Breakwater, United States Engineers, 1895,	125	200
Newport and New London, United States Engineers, 1897,	125	200
Wetumpka, Ala., United States Engineers, 1894,	90	125
Finn's Point, N. J., United States Engineers, 1897,	125	200
United States Government Army Engineers, 1894,	125	. .
United States Government Army Engineers, 1896.	100	. .
Average,	119	189
Lighthouse Engineers.		
Narragansett Bay Lighthouse Engineers,	80	. .
Office United States Lighthouse Engineers, Fifth District, Baltimore, Md., Captain Erick Bergland, August 22, 1894,	80	. .
United States Government Lighthouse Engineers,	100	. .
United States Government Lighthouse Engineers, 1896,	80	. .
Average,	85	. .
District of Columbia.		
United States Government, District of Columbia, 1895,	100	150
United States Government, District of Columbia, 1896,	125	175
United States Government, District of Columbia, 1897.	125	175
Average,	116	166
Cities.		
Wallabout Improvement, Brooklyn, 1896	150	240
Wallabout Improvement, Brooklyn, 1897.	. .	240
Easton, Pa., 1897,	150	. .

	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
City of Niagara Falls,	90	150
Washington, D. C.,	100	150
City of Baltimore,	. .	150
Reading, Pa., 1896,	150	250
Reading, Pa., 1898,	125	. .
City of Philadelphia,	170	240
Average,	134	201
Railroads.		
Columbus and Ninth Avenue Railroad, New York,	100	. .
Philadelphia and Reading Railroad,	125	. .
Metropolitan Street Railway, Washington, D. C., 1894,	100	150
Average,	108	150
Bridges.		
Topeka, Kan., Bridge, 1896,	140	200
Willis Avenue Bridge, New York,	125	200
Average,	132	200
Aqueducts, Dams, Etc.		
Pittsburg New Reservoir, 1897,	175	225
Niagara Falls Tunnel,	90	. .
Average,	132	225
Miscellaneous.		
Warren Scharf Paving Company,	100	150
Average.		
Average fifty-two specifications,	118	189
European Government specifications,	119	204

TWO PARTS SAND TO ONE PART CEMENT.

United States Engineers.		
Key West, Fla.,	150	200
Mouth Cape Fear River,	175	250
Average,	162	225
United States Lighthouse Engineers.		
Tompkinsville, S. I., 1897,	175	250
District of Columbia.		
Washington, D. C., Aqueduct, 1896,	125	200
Cities.		
Wilmington, Del.,	225	. .
New York Dock Department, 1891,	125	. .

	Seven Days. (Pounds.)	Twenty-eight Days. (Pounds.)
City of Niagara Falls,	125	200
Average,	158	200
Railroads.		
Columbus and Ninth Avenues Railroad, New York,	125	. .
Metropolitan Street Railway, New York,	125	. .
Pennsylvania Railroad,	120	175
Average,	123	175
Bridges.		
Willis Avenue, New York,	150	250
New East River,	150	. .
Average,	142	250
Aqueducts, Dams, Etc.		
New York Aqueduct, Jerome Park Reservoir, Cornell Dam,	125	200
Average.		
Average thirteen specifications,	146	216

Difficulty in Testing Cement.

Having shown you how many variations of specifications there exist, and how difficult it is for the engineer who sets out to make a specification to determine just what he wants out of all these two hundred specifications that you have before you, you can also see how difficult it is for the cement manufacturer to know which grade of cement to make to meet all these specifications, and, at the same time, to preserve what he believes the safety and the permanence of the article he produces. This is governed by the broad fact that while the work of a given engineer upon a given specification may run for two or three years, yet the cement manufacturer is in business for a life-time and he can not afford to sacrifice permanence in quality in order to obtain quality to meet a temporary or fluctuating specification. Having, therefore, all these varying specifications before him, and there being presumably at each point of destination covered by them—reaching from Portland, Oregon, to Tampa, Florida; from Portland, Maine, to New Orleans—a testing laboratory and a tester of some kind, honestly, fairly, and squarely attempting to get out of the cement delivered to him the requirements of his specification, the manufacturer is brought face to face with the

problem of what kind of a new manufactured article will each and every one of these testers make, with the water that they will provide and the cement that the manufacturer provided, into the manufactured briquettes which are to govern the rejection or acceptance of his cement. The personal equation of every testing laboratory at every piece of work must enter into the work. The character of the machinery for testing; the character of the building and of the room in which the material is tested; the character of the water with which the material is to be used; the character of the sand to be used; the temperature at which the cement and water are used; the temperature, both by day and night, of the pans in which the briquettes are to be placed; the knowledge, the skill, and the experience of the operator making the tests—are all elements with which the manufacturer, who, having finished his product at the mill, tested it in accordance with his best judgment, his best experience, must meet at a future state when the material is entirely out of his hands, before it can be used in the work. Now, I have had many years of experience in making and selling cement; many years of experience with leading engineers and well-known testers and testing laboratories, and have seen all kinds of methods of testing, from the most elaborate to the least skilled, and, broadly speaking, in every case I have found a conscientious fairness and desire to do what is right. But, with all these desires and all these good wishes, there are so many things that enter into the question of testing cement that to enumerate only a few of them will show the amount of difficulties that are to be encountered. From my own experience and from results I find in various works on the subject, I have gathered together some thirty or forty different conditions that may cover the testing of cement. They are as follows (most of them well and briefly stated in a special chapter on "Testing," in Newman's well-known book on "Cement and Concrete," published some years ago in London):

1. The nature of the slab upon which the briquettes are made, whether it be impervious or porous.

2. The method of removal of the briquette from the mold.

3. The area of the breaking section of the briquette.

4. The form of the briquette, and the proportion of its periphery to the area of the breaking section.

5. The length of time elapsing between the setting and the testing of the briquette.

6. The position of the strain as regards the breaking section of the briquette.

7. The nature of the strain, whether it be suddenly or gradually applied.

8. The time occupied in applying the strain and in making the test.

9. The form of clip for holding the briquettes.

10. Whether the clip is hung upon pivots to prevent cross-strain.

11. The equal or unequal bearing of the clips on the briquettes.

12. Whether the molds are perfectly clean and dry, or wet, before the cement is deposited.

13. Whether the mold is of iron or brass or wood, and placed on an iron plate with damp blotting-paper interposed to prevent adhesion.

14. The age of Portland cement after grinding.

15. Whether the cement has been properly air-slaked.

16. Whether a skilled operator, accustomed to testing and making the briquettes, is employed.

17. The amount of residue after the cement has been sifted.

18. Whether the briquette-mold was filled at one operation, and all air-bubbles removed.

19. The method of filling the briquette-mold.

20. Whether the briquettes are made by the same operator, the same day, under the same conditions.

21. The time occupied in gaging the cement and filling the briquette-mold.

22. Whether the mold is shaken, or tapped, to make the briquette more dense, or filled and firmly pressed by a trowel, or by other means.

23. The amount of water used in mixing.

24. The quality and character of the water used in mixing, for the soluble constituents in it may interfere with the setting; therefore it should be of the same character as that to be mixed with the concrete.

25. The temperature of the water.

26. Whether the briquettes are kept damp by wet cloths, or in a damp atmosphere, or kept dry or in water.

27. The temperature of the setting-room.

28. The temperature of the testing-room.

29. Whether the cement is hand or machine mixed.

30. Whether the materials are mixed when dry several times before being mixed in a damp or wet state.

31. The method of gaging the dry cement.

32. The season of the year the test is made, unless the testing-room is kept at a uniform temperature.

33. The exposure of a briquette to sunlight while setting. In this case one briquette out of a batch of twelve which had the early morning sun invariably checked while the other eleven were sound.

34. The sudden exposure of briquettes without covering to a current of air, leaving them at an open window. In this case briquettes have cracked right through the center, owing to sudden contraction and expansion.

35. Unskilful handling of the testing-machines and snapping of briquettes, where the machine is operated by hand.

36. Too sudden tightening of briquettes in placing them in the clips.

The following table of figures, without reference to the possibility of any of these errors having occurred, shows what results were obtained on a given sample of cement in nine different testing laboratories of the highest character in this country. They were obtained by Prof. J. Madison Porter, of Lafayette College, who sent a sample of the same cement to nine different testing laboratories:

TABLE SHOWING RESULTS OF TENSILE TESTS OF MORTAR, ONE PART CEMENT, THREE PARTS SAND (SAME SAMPLE OF CEMENT), MADE BY DIFFERENT PERSONS IN ACCORDANCE WITH THEIR UNDERSTANDING OF THE METHOD PROPOSED BY THE COMMITTEE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

(*Extract from Article by* J. MADISON PORTER, "*Engineering News*," *March 5, 1896.*)

LABORATORY.	TENSILE STRENGTH IN POUNDS OF BRIQUETTES.							RANGE IN POUNDS.	RATIO OF RANGE TO MAXIMUM.	RATIO OF AVERAGE TO MAXIMUM.	WATER PER CENT.	MOLDS.	STRUCK OFF.	HOW PLACED IN WATER.	WATER-BATH.	KIND OF MACHINE.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Av.									
1. R. W. Hildreth & C., New York.	68	72	74	78	82	...	75	14	17.1	30.4	12	Single.	Both sides.	Flat.	Still.	Riehlé. Driven by hand.
2. Washington University, J. B. Johnson.	77	94	108	110	122	...	102	45	36.9	41.8	Not known.	Gang.	One side.	"	"	Fairbanks. Johnson's clips.
3. City of Easton, H. R. Fehr, Eng.	106	112	123	...	...	...	114	17	13.8	46.5	10.4	Single.	Both sides.	Edge.	"	Fairbanks.
4. Columbia College, W. H. Burr.	125	126	130	137	140	144	133	19	13.2	54	10	"	One side.	Flat.	"	Riehlé. Driven by hand.
	126	132	138	144	150	153	140	27	17.7	56.8	8	"				
5. C. F. McKenna, New York.	148	150	151	155	160	...	153	12	7.5	62	12	"	Both sides.	"	"	Riehlé-McKenna. Rubber clips. Power driven.
6. Cornell University, F. P. Spalding.	155	160	164	166	172	...	163	17	9.9	66	Not given.	"	One side.	Edge.	Running.	Lever with bucket.
7. Lafayette College, J. M. Porter.	171	177	177	178	179	...	176	8	4.5	71.4	11	Gang.	Both sides.	"	"	Olsen-Porter. Porter's clips.
8. Clifford Richardson, Washington, D. C.	220	224	226	228	228	...	225	8	3.5	91.2	10	Single.	Both sides.	Flat.	Still.	Riehlé. Driven by hand. Rubber clips.
9. Booth, Garrett & Blair, Philadelphia.	240	246	249	250	252	...	247	12	4.8	100	12	"	Both sides.	Edge.	"	Olsen. Power driven. Rubber clips.
Average.	...	...	...	...	...	...	153	17.9	12.9	62	10.8	77.8% single; 22.2% gang.	66⅔% both; 33⅓% one.	55.5% flat; 44.6% edge.	22.2% running; 77.8% still.	66⅔% power; 33⅓% hand.

No. 2, water in bath changed once. No. 5, water not changed. No. 6, flow of water just sufficient to keep it fresh. No. 7, flow of water slight. No. 8, speed applied, 35 to 40 pounds per minute.

All molds and sand American Society of Civil Engineers' recommended sizes.

From these thirty odd out of a possible hundred points of difference, and from an examination of this table of tests, made under the best conditions, it can be readily seen that the engineer on the one hand, and the tester under him, intending to do all that conscience and right would dictate, might possibly go astray; and that the cement man, on the other hand, making the article which goes to the engineer for final test, may have, in the same way, to bear some fault that may not be directly traceable to the manufactured product as it leaves the mill.

Machinery for Testing Cement.

Having already given a summary of specifications, a summary of possible errors in the production of the completed new material,—

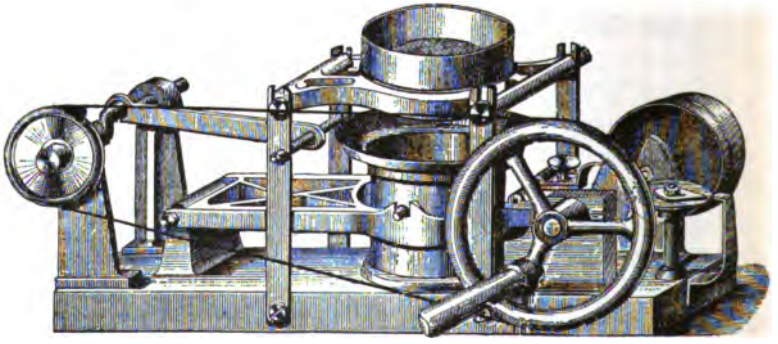


Fig. 1.—Tetmajer's Screening Apparatus.

which I shall call the cement briquette, which is a briquette of the cement as manufactured by the manufacturer,—and the labor and personal equation of the tester, I want to show, in a brief way, some of the machinery that is used in testing cement.

For Fineness.—There are many appliances in most laboratories—simple hand-screens of various meshes, in which the cement is screened by the operator by hand. The most perfect of all apparatus, however, for this purpose is that devised by Professor Tetmajer, and which is shown in figure 1. This is operated by hand, but it may be also operated by power. The fineness is determined by the residue left on the screen after so many revolutions of the wheel. Debray, in Paris, has a machine of somewhat similar construction for the same

purpose, but in this country there are, to my knowledge, few, if any, mechanical screens in operation.

Time of Setting.—This is another important element in the test, and one in which many differences of opinion occur, and personal equations differ largely in many laboratories.

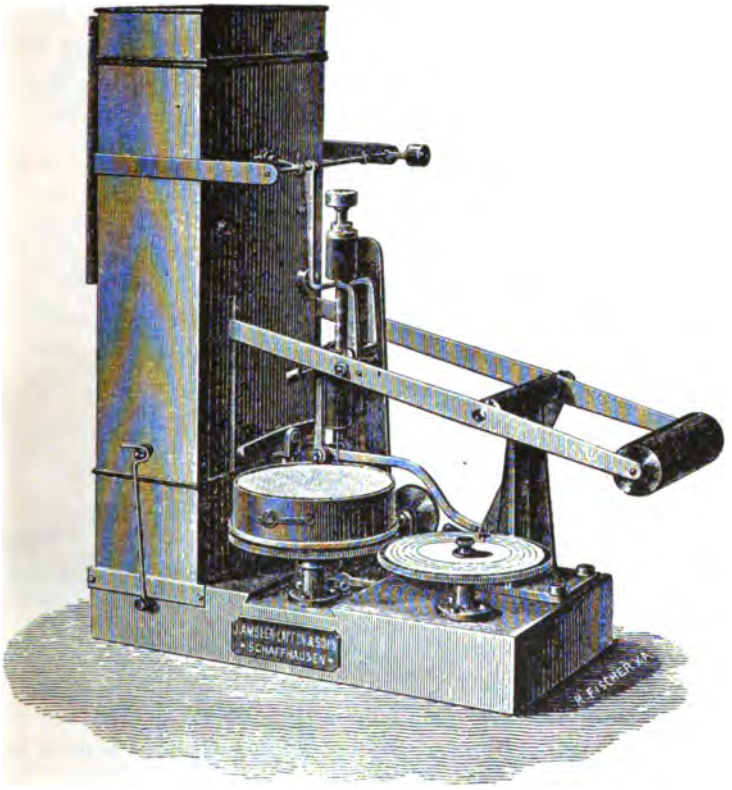


FIG. 2.—TETMAJER'S NEEDLE.

The cause is easily arrived at by an examination of the ordinary form of Vicat's needles sold by the manufacturers of testing apparatus, and used in most laboratories on the work, as well as in large cities. This needle, of two sizes, is used to determine the initial and final set, and is held by the operator on the pat or briquette when made, and the time of setting is arrived at by taking the moment when it ceases

to penetrate the material. The possible chance of error can readily be seen. John Grant, the engineer of the Metropolitan Drainage, London, in 1859 sought to improve on this crude form of needle, and devised a special form of apparatus for determining the time of setting.

An improved form of this apparatus is used by Debray in the testing laboratory of the Ponts & Chaussées, in Paris, and is described and illustrated in the "Cahier Guillain," which is the leading French Government specification, and in use on practically all Government work. Many of the forms of apparatus used in France are those

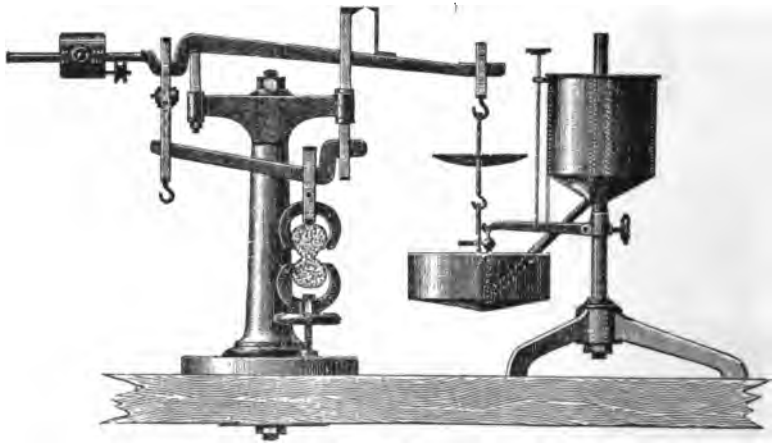


FIG. 3.—MICHAELIS CEMENT-TESTING MACHINE.

recommended by a Government Commission of Engineers, who spent several years in examining the subject, and whose report is most interesting. This French apparatus I have not illustrated, as it so closely resembles that of Tetmajer, of the Swiss Government Polytechnicum at Zürich—the most complete laboratory for the testing of structural materials in the world. These forms of needles are shown. They are, as can be seen, simple in construction and use. The final evolution in this form of apparatus is shown in Professor Tetmajer's latest machine. It makes a diagram from which it can be ascertained, first, the interval of time from the moment water is applied to the cement and the beginning of the hardening; and, next, the time to the begin-

ning of the final hardening. This apparatus is practically automatic and self-registering. The method of its operation is very complex, and would involve a description too long for the present paper.

Tensile Strain.—The apparatus for testing the tensile strain for cement may broadly be said to date from John Grant's work on the "London Drainage," so fully described by Reid in his book, and

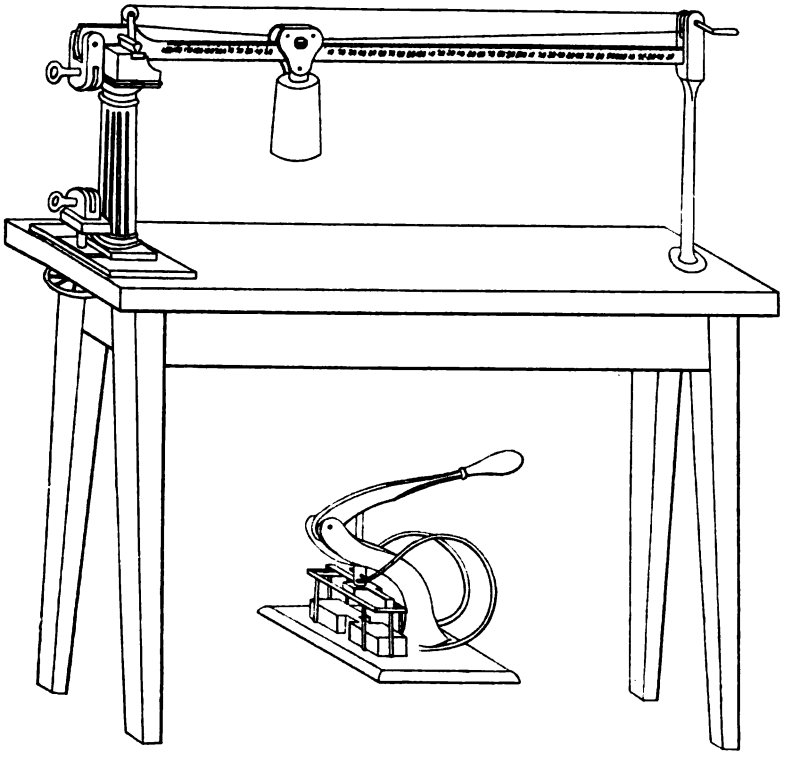


FIG. 4.—GRANT'S CEMENT-TESTING MACHINE, MOLD AND PRESS.

by Grant himself in his papers before the British Institute of Engineers.

Grant's machine is shown, together with mold and press. This apparatus, which is the foundation upon which the modern Riehlé and Olsen testing-machines are built, is very simple and direct. General Gilmore, the distinguished American engineer, sought to test his cement

in another way and devised another type of machine. This consists in placing the prisms to be broken on two supports and by running shot into a pan suspended on a registering dial, to bring down the long arm of the apparatus, which in turn, by raising up the short, pivoted

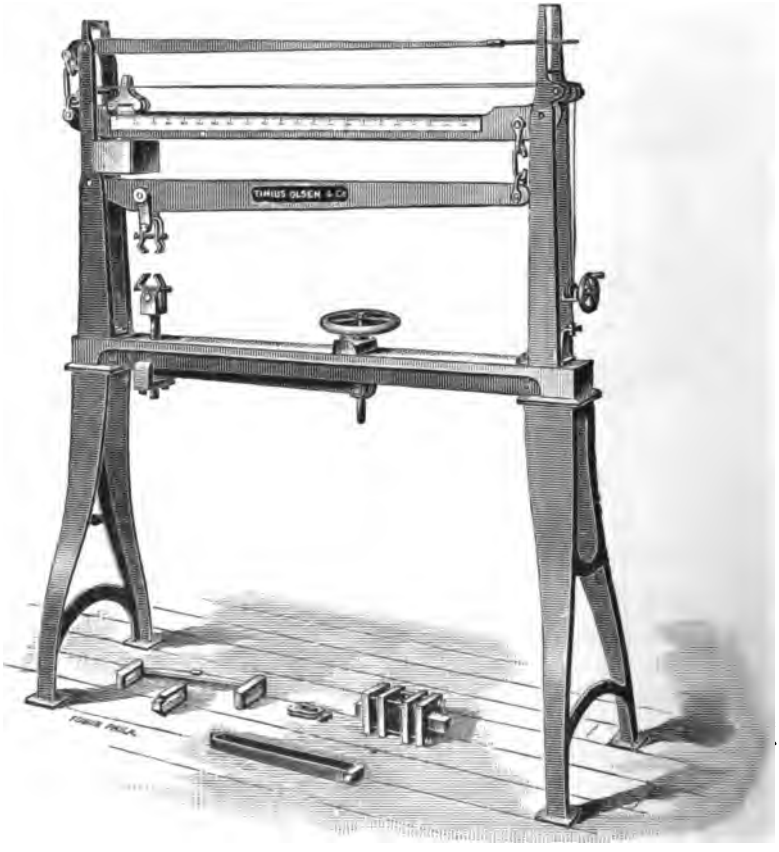


FIG. 5.—OLSEN CEMENT-TESTING MACHINE.

arm resting on the prism, causes the lower end to press upon and break the prism. A modern form of machine is the Michaelis, largely used in Germany and France. A form of this apparatus, operated by a spring controlled by a column of oil, is in use in England. The Michaelis machine has its counterpart in this country in the Fairbanks

tester. As already mentioned, the original Grant machine has been improved on by American skill, and the result is shown in the Riehlé apparatus. The Olsen machine resembles the Riehlé in general principles and form, a principal point of difference being in the placing

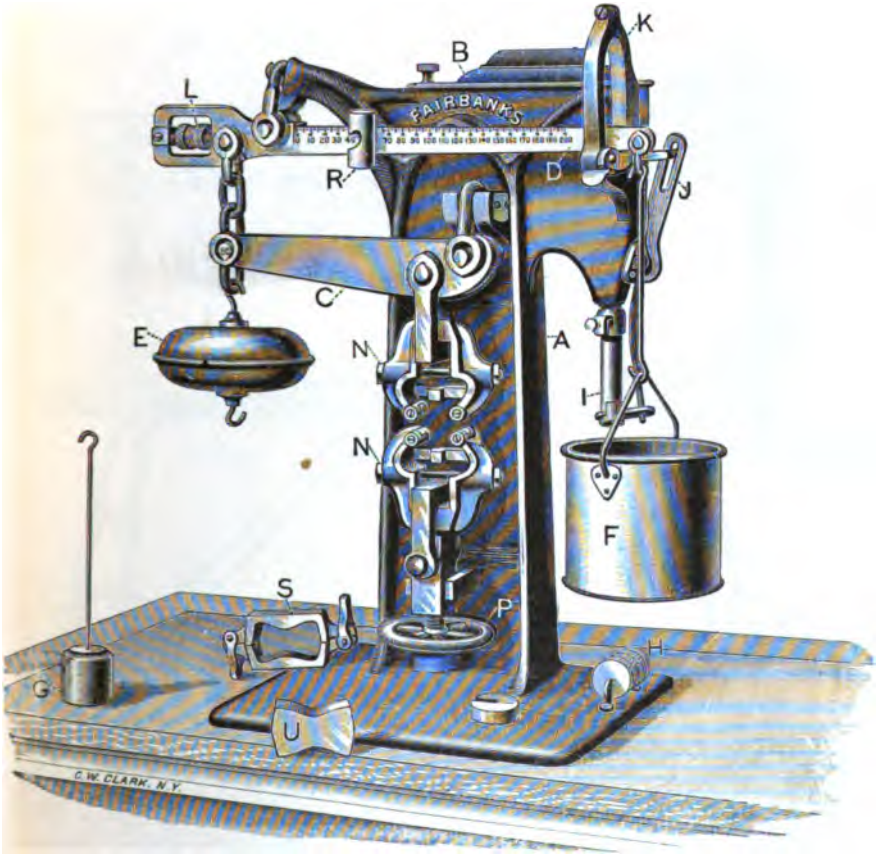


FIG. 6.—FAIRBANKS CEMENT-TESTING MACHINE.

of the clips. This briefly describes the evolutions of the testing-machine and the final machines now in use.

The making of briquettes gives rise to many difficulties. In most countries they are made by hand. Germany, however, has evolved a

machine for producing a uniform pressure by hammer blows on the material after it is placed in molds.

The German hammer apparatus is operated in the Royal Testing Station at Charlottenburg, near Berlin. Other similar machines are operated by hand in smaller German laboratories, while Professor

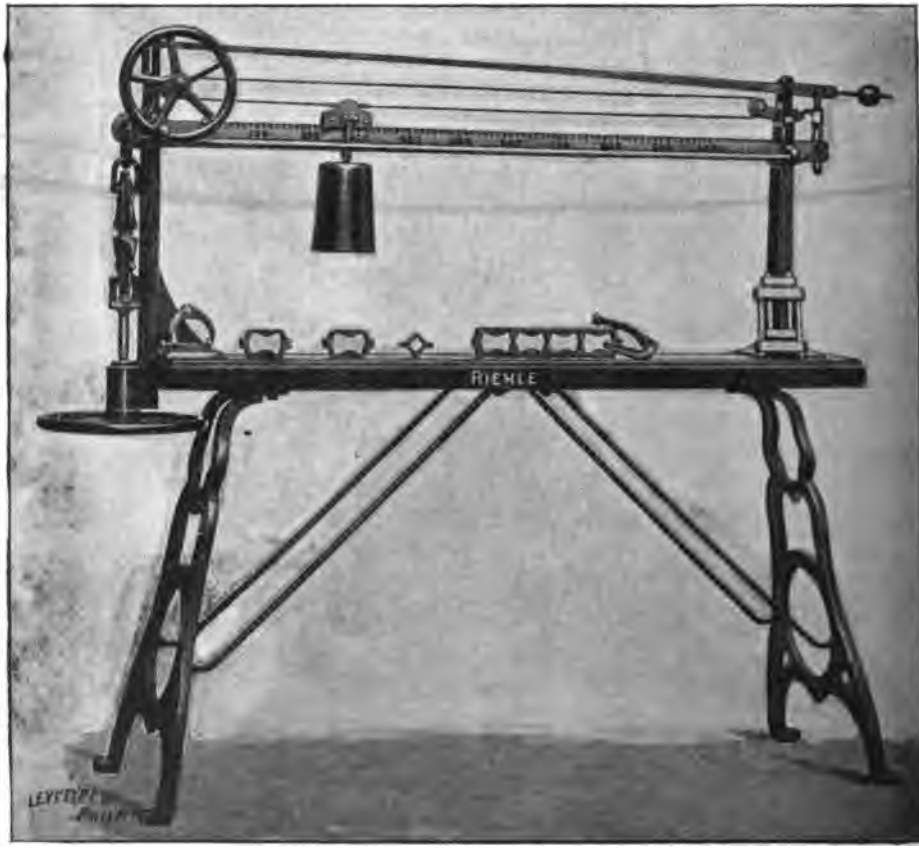


FIG. 7.—RIEHLÉ CEMENT-TESTING MACHINE.

Tetmajer in his laboratory uses power. These machines are used for preparing samples for both compression and tensile tests. In this country Riehlé has gotten up an apparatus on similar lines.

For mixing the materials to be used in making the briquettes, a

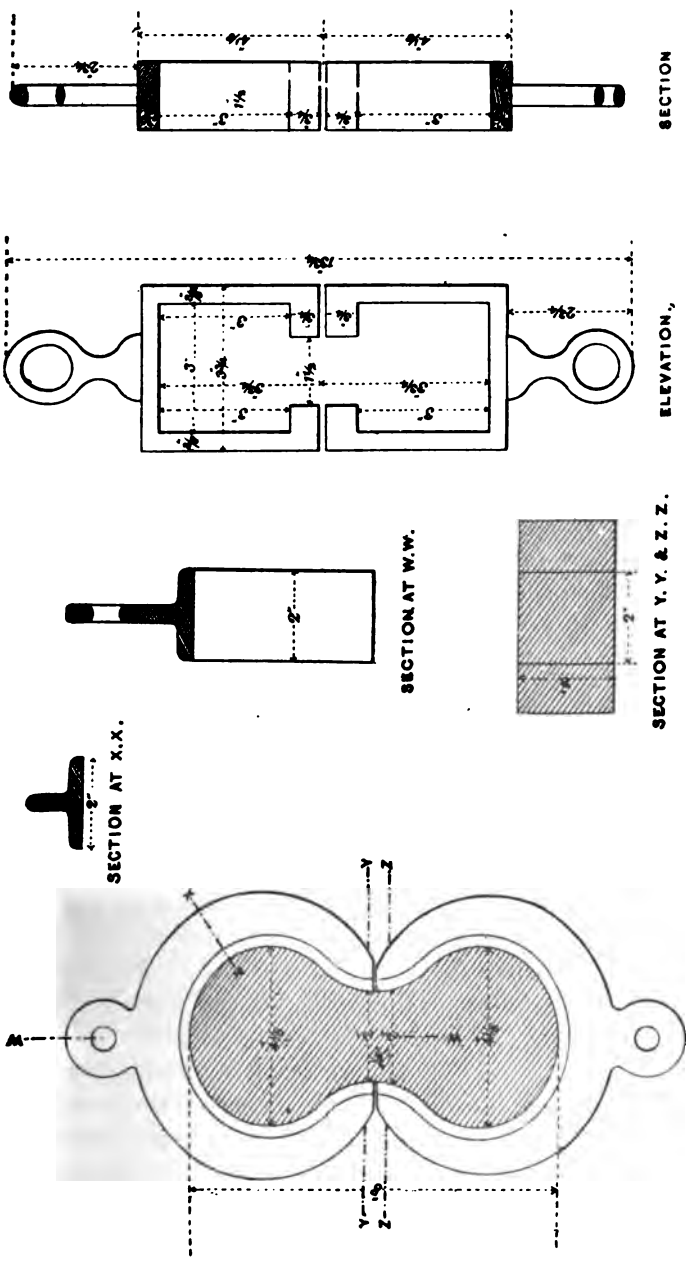


FIG. 8.—TYPES AND DETAILS OF BRIQUETTE-MOLDS.

machine was devised by Faija, the leading English authority. Professor Spalding, of Cornell, devised an apparatus of the same general character.

Other Tests.

As the tables of specifications given embrace principally and only the three general classes of tests I have illustrated, and as these present so many differences and so many opportunities for honest error and mistakes in conclusion, I have not gone into the many other tests which may be embraced in a specification.

There are tests for compression largely used by Tetmajer and the German experts, and in which cylinders and cubes of cement are crushed by hydraulic presses; tests for constancy of volume in which, by many specifications, pats of cement in air and water are observed for a period of twenty-eight days for checking and cracking; while by other specifications they are submitted to accelerated tests by heat, by boiling, cooking, stewing, simmering, and other forms of violence for the same purpose; tests for adhesion, tests for porosity, tests for density, tests for specific gravity, and chemical tests of all kinds and sorts.

Testing-Laboratories.

It was my intention, in completing this paper, to give a more extended description of the leading laboratories in Europe and in this country than I have given, but I find that to do this would involve traveling over a very large field and taking up a great deal of time. Suffice to say that what I have shown of the machinery used in testing cement and of the methods in general use is drawn in most part from an experience and examination of the apparatus of the Royal Testing Station at Berlin, as exhibited by Professor Gary at the World's Fair, Chicago; of the testing-laboratories of Professor Tetmajer, at the Polytechnicum at Zürich; of the French Ponts et Chaussées, at Boulogne and Paris; of Faija, in London; and of the well-equipped laboratories of the United States Government at Washington; City of Philadelphia, in Philadelphia; the New York Aqueduct at Croton and Jerome Park, N. Y.; the Chicago Drainage, at Chicago; the St. Louis Water Board, at St. Louis; the Metropolitan Aqueduct, at Boston; and the private laboratories of R. W. Hunt & Company, in Chicago; Booth, Garrett & Blair, and Lathbury &

Spackman, in this city, and Dr. McKenna, of New York, at all of which testing under the most improved methods and with the least possible fluctuation is done. In addition to this a large experience, covering testing bureaus on public works of all kinds, from the smallest to the most important, embracing railroads, bridges, sewers, paving, architecture, and other construction, has given me a considerable knowledge of the method adapted to this grade of laboratory and this character of work.

Conclusion.

From this wide experience, covering nearly a quarter of a century, and embracing personal contact with testers and testing-laboratories and from those of the most scientific character to the most unskilled nature, I have come to the conclusion that the testing of cement is a most difficult branch of the engineering profession; that in the making of specifications, or in the laying down of methods of making tests and modes of manipulation, it is almost impossible to make such specifications that will apply equally to the laboratories of both cases and to testing of both of the varying conditions that exist in the two kinds of laboratories. For this reason it is gratifying to find that of late years there is gradually coming in the minds of the engineers and of the consumers of cement a distinction between the well-equipped, well-established, well-managed, scientifically constructed, scientifically appointed laboratory, and the ordinary laboratory or testing-room on work all over the country. This distinction is very strongly drawn in a recent specification of the Russian Government, some extracts from which are given, and also in a recent specification of the Master Builders' Association of Philadelphia, which, I understand, has been adopted by some of the other master builders' associations of the United States.

Extract from Russian Government Specifications.

A mixture of 1 part cement to 3 of normal sand, twenty-eight days after setting, must bear, as its minimum power of resistance to rupture, a strain of 8 kilograms to the square cm.,—*i. e.*, 113.4 lbs. to the square inch.

To attain all possible uniformity of quality, in cases where cement

of the same brand is received in several lots, tests of pure cement are made.

In choosing cement for construction, preference is given to that factory whose cement—all other qualities being equal—gives the greatest resistance to rupture after seven days, tested pure.

Pure cement after seven days must, when tested by rupture, bear a strain of no less than 21 to 25 kilogm. on the square cm.,—*i. e.*, 297.72 to 354.50 lbs. to the square inch.

When the normality of a cement is determined in a laboratory, then, simultaneously with the test described in Rule 6,—*i. e.*, after twenty-eight days,—a test of the mortar after seven days must be also made, and a proportional comparison of this latter test with the resistance offered by the mortar after twenty-eight days is completed.

It is necessary to know this proportion when making quick control tests.

Mortar consisting of 1 part cement and 3 parts of normal sand, whose power of resistance after twenty-eight days is 8 kilogm. on the square cm.,—*i. e.*, 113.4 lbs. to the square inch, and to resist after seven days to a strain of no less than 5 kilogm. to the square cm.,—*i. e.*, 71.12 lbs. to the square inch.

All the above tests enumerated in the preceding rules determine the normality of a cement of a given brand.

For cement of a known brand, in order to save time (especially when tests are necessary at the locations of constructions), control tests are allowed, these considerations determining:

(*a*) The time of setting.

(*b*) The property of briquettes made from pure cement, to remain free from cracks and warpings during seven days.

(*c*) The fineness of the grain.

(*d*) The resistance to rupture after seven days' testing of pure cements, and also its mixture with sand.

The power of resistance of a mortar composed of 1 part of cement to 3 of normal sand, seven days after being mixed, must in no case be less than 6 kilogm. on the square cm.,—*i. e.*, 85.34 lbs. to the square inch.

Should the cement respond to all requirements from *a* to *d*, excepting *d*, the tests may be adjourned for twenty-eight days, when the

cement must undergo all the tests provided for in Rule 6. (See first paragraph.)

Extract from Philadelphia Master Builders' Exchange Standard Specification for Cement.

Classification of Manner of Testing.

Two classes of tests shall be optional.

Class 1 contemplates the conduct of the tests in a laboratory designated by the purchaser, having all the necessary facilities and appliances for insuring accuracy and refinement of tests.

Class 2 shall be tests made with more crude facilities and appliances, such as can be readily obtained at or near the site of the work, and where the specified conditions as to temperature, moisture, and mode of preparing test specimens can not be fully met.

The purchaser reserves the right to take samples from each lot or each barrel or bag of cement delivered, and to subject them to tests, either under Class 1 or 2, and to accept or reject the cement in accordance with the results of the tests.

Tensile Strength.—The average tensile strength in pounds per square inch of section of each set of five specimens, one hour in air and the remainder in water, shall not be less than:

	Class 1 Test.			Class 2 Test.		
	One Day.	Seven Days.	Twenty-eight Days.	One Day.	Seven Days.	Twenty-eight Days.
Natural Cement.						
Neat,	75	150	225	50	125	200
One cement to two sand,		80	140		50	100
Portland Cement.						
Neat,	125	400	500	100	300	400
One cement to three sand,		125	200		90	150

The requirements of testing in these two specifications are distinctly modified, as between the laboratory on the work and laboratory of the trained expert; and this, to my mind, seems proper and right, and is a move in the right direction, and is one in which, I think, engineer, consumer, and cement manufacturer should

cooperate. It may with propriety be argued that, in view of the fact that there exists these well-equipped laboratories, managed by leading experts of the country, the laboratory on the work is a back number and has no further cause for existence, that all cement should be tested in these better equipped laboratories, and that the test-room on public work at the place of construction should exist no longer. This argument would apply with great force were it possible to ship the cement to the scientific laboratory and have it tested there, or were it possible for the scientific laboratory to locate itself upon the large works that are being done in all the wildernesses of ours; but these conditions do not and can not, under the present scope of engineering work, exist. Consequently, the testing of cement on its arrival at the place of consumption, in the laboratory under the direct supervision of the engineer, whose reputation is at stake in the work, will and must go on for the reason that any other course would involve delay in the work, and would in some way deprive the engineer in charge of the work of the direct supervision of the manufacture of this new article, the cement briquette, which, in its form of mortar, is to be the binding material of his work. Consequently, to my mind, there seems to be but one answer to the question of how cement shall be tested, and that is, that there shall be distinct differences made between the specification for cement to be tested in the ordinary laboratory on public work and cement to be tested in the laboratory of the skilled expert. The main object of the engineer who is using the material on the work is to know that the material he is receiving is of the quality of the material he is contracting for. It would seem to me proper and right, therefore, that at the beginning of any large piece of work the services of the trained expert of the well-equipped laboratory should be called in to determine that the cement offered is of a fixed standard, and at the same time a sample of the same cement should be tested in the laboratory of the engineer on the work, to determine what results it gives under the conditions of that particular laboratory with that particular tester. When these two facts have been determined, subsequent tests of the cement should be made on the work by the assistants of the engineer in the laboratory on the work, and the manufacturer should be held to deliver at all times a cement similar to that of the first sample submitted as tested by the laboratory on the work. It should further be provided, in

the event of a difference arising at any time between the manufacturer and the engineer as to the quality of the material or methods of tests in the laboratory on the work, that at that time the services of the skilled expert and the well-equipped laboratory should be called in. In other words, that the engineer who is responsible for the work should, practically under his own roof, and with his own employees, control the testing of the material which is to enter into the work for which he is responsible, but that at all times there should be left an appeal to a scientific laboratory, which should act as judge between the manufacturer and engineer.

A FEW REMARKS ON THE TESTING LABORATORY OF THE CITY OF PHILADELPHIA.

RICHARD L. HUMPHREY.

Read April 1, 1899.

It is nearly three years ago that I had the pleasure of presenting to the Club a paper on "The Cement Laboratory of the City of Philadelphia: Its Equipment and Methods." Since that time there has been a gradual development in the scope and the amount of work accomplished, and I desire to claim your attention while endeavoring to describe some of the additions in the equipment of the laboratory, and to give some of the results of tests which have been made.

The sieving apparatus to which reference was made in my former paper has been installed, and is in constant service. Prior to the installation the sieving was done by hand; the operation was slow and laborious, which produced an unconscious tendency to slight the work. The sieving apparatus now in use is shown in figure 1. It is operated by a small electric motor, and consists of a wooden frame (1 foot 10 inches long, 14 inches wide, and 10 inches deep) supported by four legs; a box, 14 inches long, 10 inches wide and deep, fits closely into the frame. This box has trunnions in the center of two sides, which move in grooves in the outside frame; and is moved to and fro by a crank connected to a crank disc having a throw of $1\frac{1}{2}$ inches. The box holds four sets of brass sieves, each set consisting of a No. 100 and a No. 200 sieve, a cover, and a pan, all nesting into each other. These sieves are held in place by means of two clamps. The driving pulley makes 100 revolutions per minute, and the box holding the sieves makes 200 movements per minute, to and fro. The sieving frame has a tilting motion, and the rapidity of the motion imparts to it a jerking movement.

The sieving is continued until not more than $\frac{1}{10}$ of one per cent. passes through the sieves after five minutes' continuous sieving.

For the determination of the abrasive qualities of materials by im-

pact and wear, a machine (Fig. 2), usually known as a rattler, has been installed.

This apparatus consists of a cast-iron polygonal barrel, 30 inches in

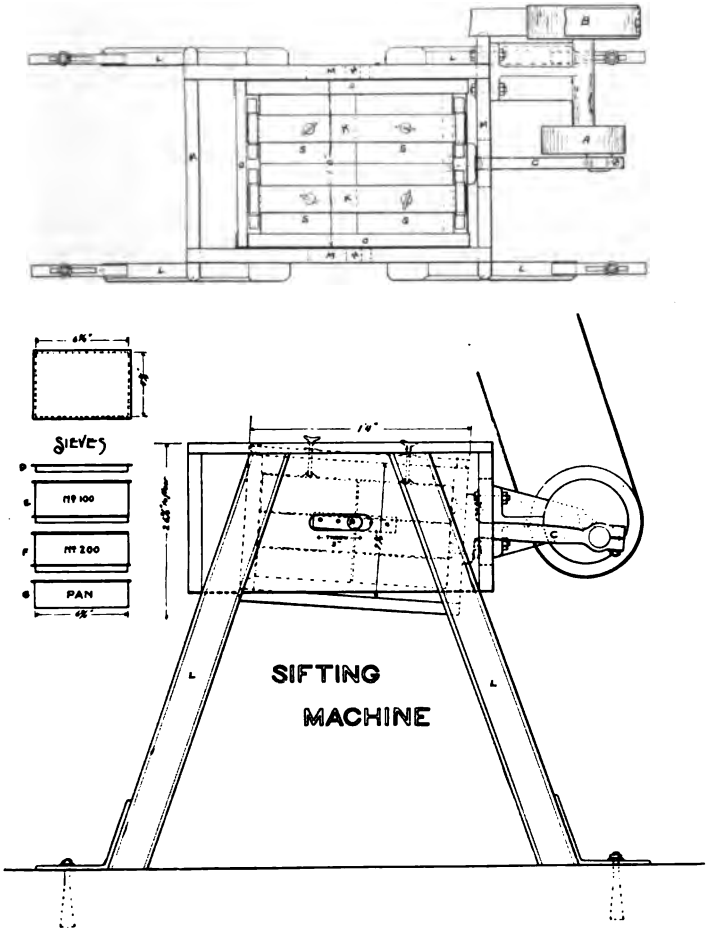
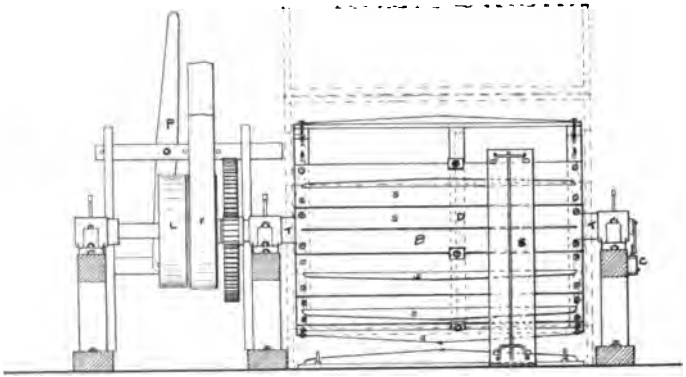
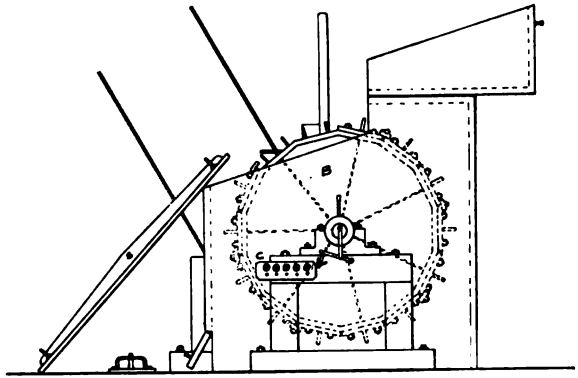
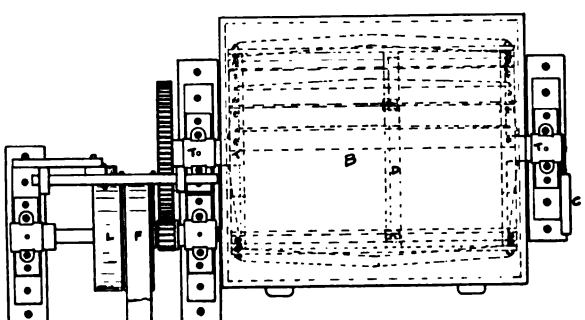


FIG. 1.—DETAILS OF SIFTING MACHINE.

diameter and 42 inches long, having 14 staves $\frac{1}{4}$ of an inch apart. Two of these staves can be removed for the purpose of inserting the charge. There is a movable diaphragm in the barrel, which permits reducing the working or test-chamber to any desired size less than







MACHINE
FOR
IMPACT AND ABRASION TESTS
TESTING LABORATORY —— CITY HALL
PHILADELPHIA

SCALE
FEET

Notes: Drum 28⅝ in. diam. X 40⅛ in. long inside
Length of testing chamber variable by movable diaphragm
14 staves each 6¼ in. wide separated by ¼ inch spaces
38 revolutions per minute.

FIG. 2. DETAILS OF IMPACT AND ABRASION MACHINE.

42 inches. The barrel rests on trunnions, and is driven by gearing which gives it a motion of about thirty-five revolutions per minute. A five-figure counter records the number of revolutions.

In some tests cast-iron bricks are used as the abrading material; these bricks are 5 inches long, 3 inches wide, and 1½ inches thick, and weigh about six pounds each. The barrel is entirely incased in wood to confine the dust and deaden the noise.

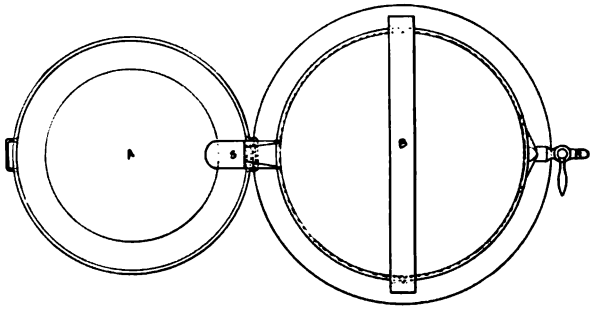
Three methods for determining the percentage of loss are being tried: (1) The charge is made up of the brick under test equal in volume to fifteen per cent. of the volume of a test chamber 30 inches in diameter and 20 inches long; (2) the charge is equal in volume to fifteen per cent. of the volume of the test-chamber, and consists of 100 pounds of cast-iron bricks, and the balance is made up of the bricks under test; (3) Johnson's method, in which the charge consists of 10 cast-iron bricks and five of the bricks under test.

For determining the specific gravity of brick, blocks of stone and concrete, etc., the apparatus shown in figure 3 has been constructed.

It consists of a heavy sheet-copper tank, tinned on the inside, 1 foot 6 inches in diameter and 1 foot 8 inches high. Into the top of this tank fits a cup 6 inches deep and ¼ of an inch less in diameter than the tank. Across the top of this cup is fastened a brass strip, which projects beyond the sides of the cup, and when the latter is in position the brass strip rests on two lugs on the sides of the tank. The bottom of the cup extends ⅛ of an inch below the normal level of the water in the tank. The cup is made convex on the bottom to prevent the collection of air-bubbles. The normal level is maintained at the same height by means of an L-shaped spout having a two-inch circular orifice. The lower point of the elbow of the spout is ¼ of an inch below the upper edge of the opening made by the spout into the tank. A spigot at the lower part of the tank permits of emptying the tank at the end of the tests.

To use the apparatus the cup is lifted out and the tank is filled with water until it overflows through the spout. The cup is then placed in position, and brought to a bearing on the brass lugs. The cup forces out a small quantity of water and changes the level of the water in the tank from a variable level to a constant artificial level. An aluminium pan having a capacity of about 3½ gallons is placed under the spout. The cup is carefully lifted out from the tank and placed

over the pan, so that the drippings are not lost. The brick or block of stone to be tested, having been previously weighed, is placed in the tank; the cup is then gently replaced, thus restoring the former artificial level. The water in the pan is that which has been displaced by the brick or block of stone. The weight of this water represents the



SPECIFIC GRAVITY APPARATUS

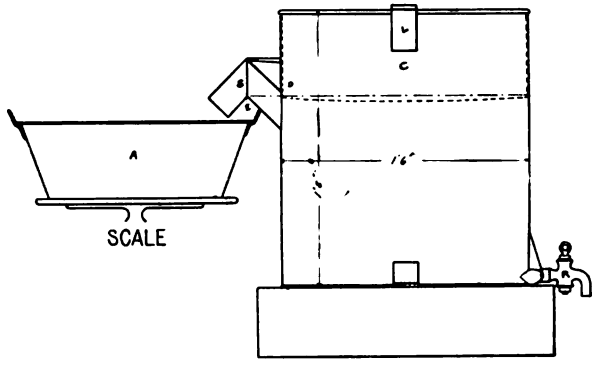


FIG. 3.—DETAILS OF SPECIFIC GRAVITY APPARATUS.

displaced weight, or the loss of weight in water, and the specific gravity is obtained by dividing the weight in air by the loss of weight in water.

This test is made on bricks or stones, etc., which are thoroughly saturated with water, usually immediately after making the absorption test; a correction being made for the water absorbed by the brick or

Motor. Sifting Machine. Impact and Abrasion Machine.

FIG. 4.—VIEW IN PHYSICAL LABORATORY.

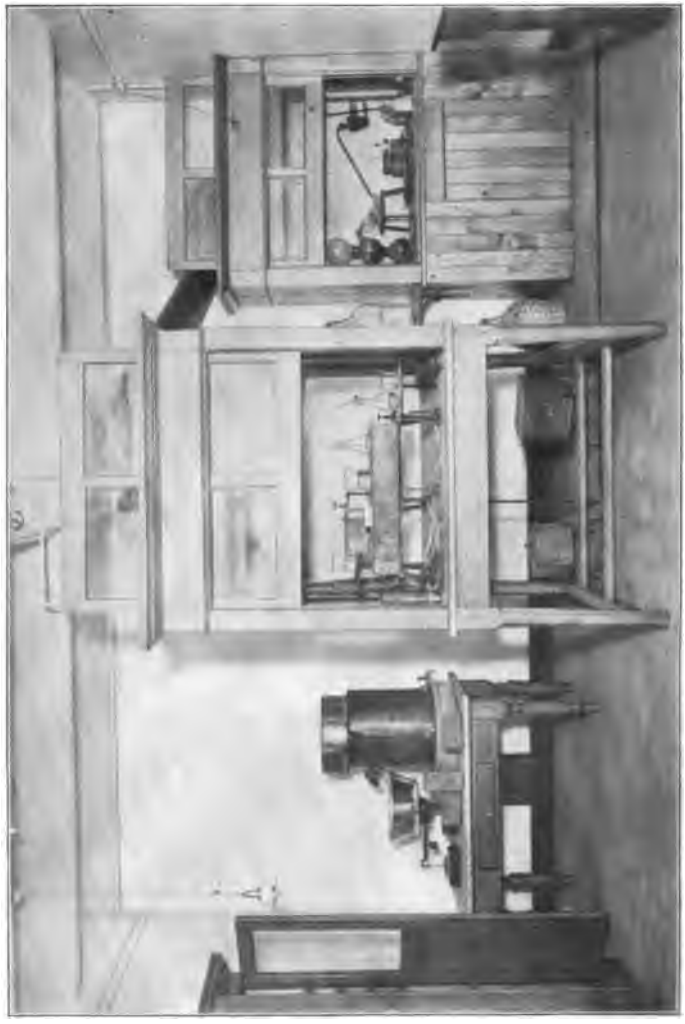


FIG. 5.—VIEW IN CHEMICAL LABORATORY.

stone. The results by this method are accurate to the second decimal place.

For preserving concrete test-cubes, and making absorption tests, a soapstone tank has been added; this is 7 feet long, 30 inches wide,

FIG. 6.—VIEW OF OVER 20,000 BROKEN BRIQUETTES.

and 16 inches deep, and is provided with a supply of running water maintained at a constant temperature.

These are the principal new features in the laboratory equipment; the minor additions, which have been provided to facilitate the work and bring the laboratory up to a high standard of efficiency, are too numerous to permit of mention at this time.

Before considering some of the results of the tests made in the laboratory, I desire to correct an error which appears in remarks in closing the discussion on "The Cement Laboratory of the City of Philadelphia: Its Equipments and Methods." In this closure I quoted the Le Chatelier formulas as they were printed in the paper read before the Congress of Engineers at Chicago in 1893. In response to my letter to the American Institute of Mining Engineers, in the transactions of which Professor Le Chatelier's paper was published, Mr. R. W. Raymond, the Secretary of the Society, stated that as the final proof of this paper had been corrected and approved by the author, he therefore assumed that the formulas were correctly reproduced. I wrote to Professor Le Chatelier, calling his attention to the formulas, and asking him if they were correct. He replied as follows:

"The formulas that I have given to define the comparative limits of Portland cement are:

$$\frac{CaO + MgO}{SiO_2 - Al_2O_3 - Fe_2O_3} \geq 3$$

$$\frac{CaO + MgO}{SiO_2 + Al_2O_3 + Fe_2O_3} \leq 3$$

"Latterly, having recognized that the tricalcium ferrites slake like lime, I have modified the second formula in the following manner:

$$\frac{CaO + MgO}{SiO_2 + Al_2O_3} \leq 3$$

"But I have never given the formula—

$$\frac{CaO + MgO}{SiO_2 + Al_2O_3 - Fe_2O_3} \leq 3$$

"If it is found in my memoir of the Congress of Chicago, it is an error that I have permitted to escape me in correcting the English translation."

In my remarks, therefore, in formula 2, $-Fe_2O_3$ should read $+ Fe_2O_3$, and in column 2 of the table 3.1 should read 2.6, and 3.2 should read 2.7.

In the last six years over four thousand samples, covering all grades of natural, Portland, slag, and sand cements have been examined and tested. In making these tests over sixty thousand briquettes have been molded, of which over fifty thousand briquettes have been

broken, and the remainder, over six thousand, will be broken at intervals up to ten years. A glance at the view on page 185 will give some idea of the work required in molding and breaking over fifty thousand briquettes. This view is from a photograph of a pile of broken briquettes seven feet high, containing over twenty thousand briquettes, representing a trifle over two years' work.

In making these tests many interesting phenomena in the behavior of cement have occurred; I have selected at random a few of the most characteristic occurrences to show some of the vagaries in the hardening of cement.

The following tests are from a natural cement, which cracked and checked badly after three days' immersion in water, and at seven days there was a decided loss of strength and signs of disintegration:

	Tensile Strength in Pounds per Square Inch.				
	Twenty-four Hours.	Seven Days.	Twenty-eight Days.	One Year.	Four Years.
Neat cement, ...	135	94	28	218	530
1 cement, 2 sand, . . .	148	219	41	. .	394

The condition of all the briquettes is shown in figure 8 (upper diagram). The twenty-eight-day tests are the average of three briquettes; the neat briquettes gave a minimum strength of twenty pounds and a maximum strength of thirty-four pounds, while the sand (standard quartz) briquettes gave a minimum strength of thirty pounds and a maximum strength of forty-six pounds. At the end of one and four years the tests showed that the cracking and checking had ceased and that the cement was hardening. And notwithstanding the fact that the briquettes were all badly cracked and checked, as those shown in figure 7, they yielded excellent results, tested in tension.

Here are some briquettes of natural cement made from mortar taken from the mixing-box on actual work:

	Tensile Strength in Pounds per Square Inch.		
	Four Months.	Six Months.	Three Years.
1 cement, 2 bar-sand, . . .	150	168	313

These briquettes during the first stages were apparently disintegrating, and were so soft that it was impossible to obtain any strength from them at the usual periods of seven and twenty-eight days; they were, however, carefully preserved in water, and at four months had hardened and developed considerable strength.

It is a frequent occurrence for natural-cement briquettes composed

of 2 parts of standard quartz-sand and 1 of cement to develop greater strength than the neat-cement briquettes.

This is shown by the following tests:

	Tensile Strength in Pounds per Square Inch.			
	Twenty-four Hours.	Seven Days.	Twenty-eight Days.	Three Years.
Neat cement, ...	139	278	337	493
1 cement, 2 sand, ...	86	201	280	596

Another remarkable test was obtained from briquettes made from mortar taken from the mixing-box, and composed of one part natural

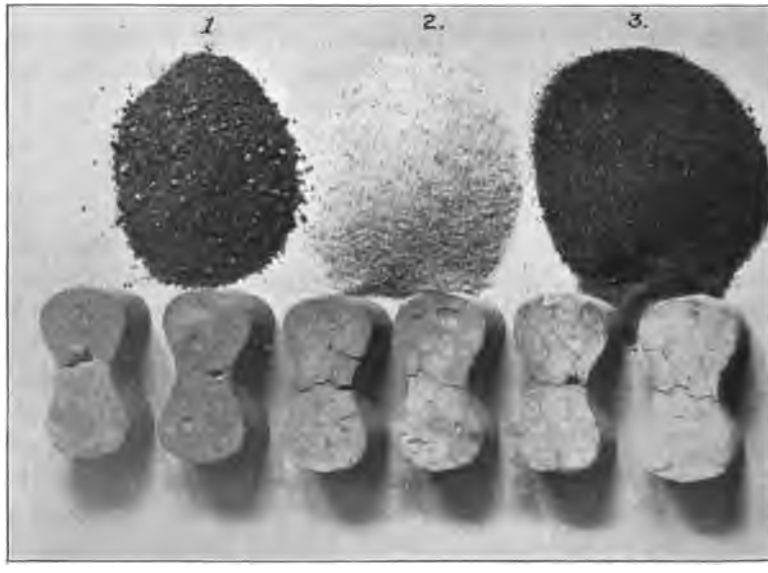


Fig. 7.—View of Gravel, Standard Quartz, and Bar Sand; also Checked and Cracked Briquettes.

cement and two parts bar-sand. These briquettes were preserved on the work, having been immersed in water after hard-set, and were subsequently frozen solid in the pan in which they had been immersed. In spite of this usage they developed the following tensile strengths:

	Tensile Strength in Pounds per Square Inch.			
	Seven Days.	Twenty-eight Days.	Two Months.	Three Years.
1 cement, 2 bar-sand, . . .	58	93	173	603

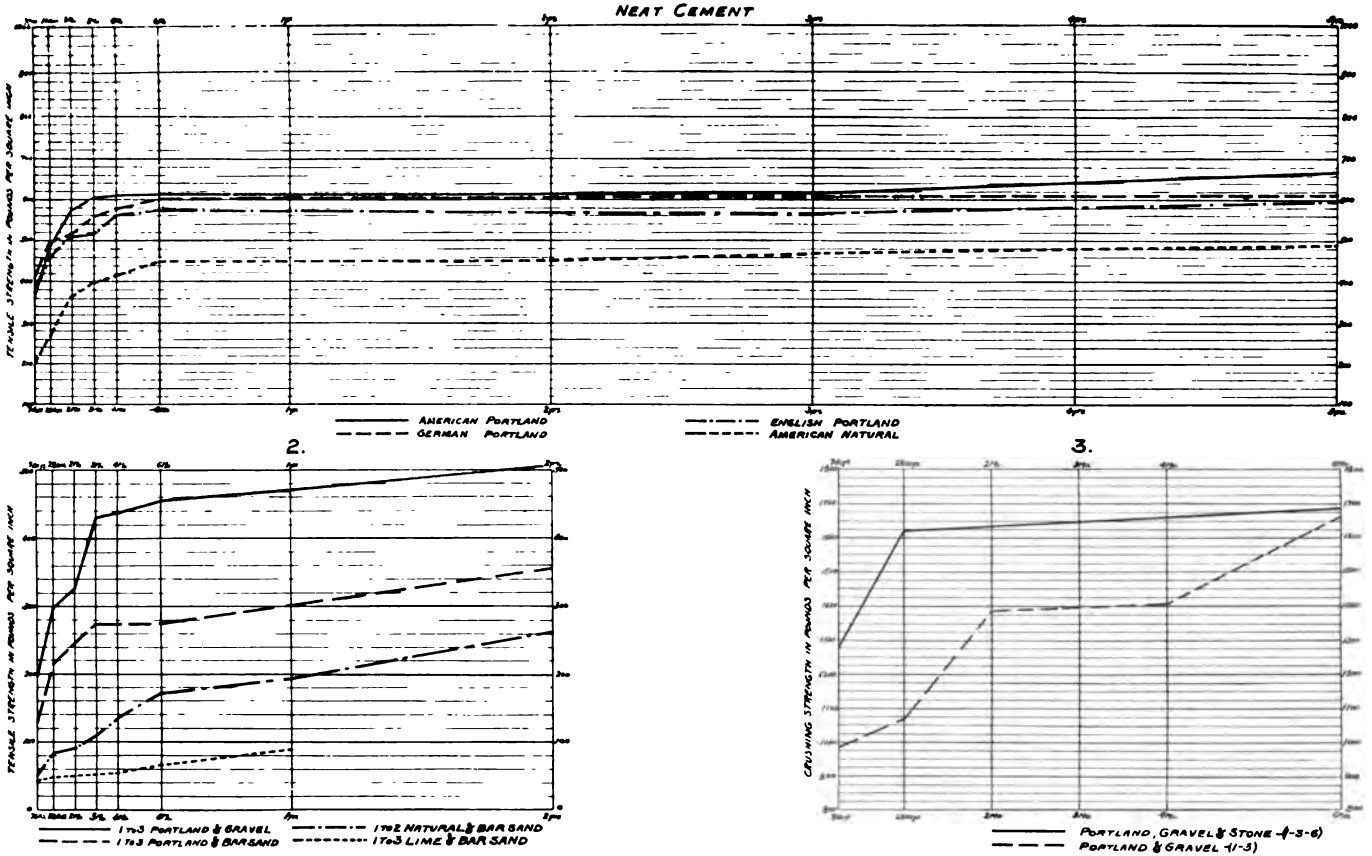

NEAT CEMENT
TENSILE STRENGTH IN POUNDS PER SQUARE INCH
AMERICAN PORTLAND
GERMAN PORTLAND
ENGLISH PORTLAND
AMERICAN NATURAL
2.
TENSILE STRENGTH IN POUNDS PER SQUARE INCH
1 to 3 PORTLAND & GRAVEL
1 to 3 PORTLAND & BAR SAND
1 to 3 NATURAL & BAR SAND
1 to 3 LIME & BAR SAND
3.
CRUSHING STRENGTH IN POUNDS PER SQUARE INCH
PORTLAND, GRAVEL & STONE (1-3-6)
PORTLAND & GRAVEL (1-3)

FIG. 8.—AVERAGE RESULTS OF TESTS OF CEMENT MADE IN LABORATORY AND ON THE WORK.

It has been my experience that retempering natural cement greatly reduces its early strength and generally impairs its ultimate strength. If, however, the retempering has not been too great, the cement will very gradually acquire strength.

The tests I have selected to illustrate this point were obtained from briquettes made from natural-cement mortar taken from the mixing-box on the work. The mortar had been retempered at the mixing-box by the mason's helper and by the mason himself; yet, notwithstanding this, the cement gradually developed strength, although it gave very poor short-time tests. The tests are as follows:

	Tensile Strength in Pounds per Square Inch.		
	Seven Days.	Twenty-eight Days.	Four Years.
1 cement, 2 bar-sand, ...	35	55	535

In order, however, to give general ideas of the results of the tests of cements, I have prepared the accompanying diagrams, in which the results of the tests have been grouped into class averages.

In upper diagram, figure 8, results are shown of the tests of cement made over five years ago. It will be observed that there is no notable increase in strength beyond that attained at the end of six months. One interesting feature of the diagram is the showing made by the American natural cements; these cements, under the superior manipulation in the laboratory, prove to be close competitors of the Portland cements of five years ago.

It is customary, on all work of importance, to test the value of cements by making briquettes from mortar taken directly from the mixing-box.

In the construction of the subway along Pennsylvania Avenue it was necessary to underpin many of the buildings along the line of the work; in some cases this necessitated rebuilding the brick walls. This brick-work was laid up in lime mortar.

A series of briquettes were made from the lime mortar, used in this work, taken direct from the mixing-box. These briquettes hardened very slowly, and could not be removed from the molds until they were three or four days old. If placed in water as soon as they were removed from the molds, they gradually dissolved into a soft mass. They had, therefore, to be preserved in air, although they could be preserved in water after one or more months' exposure in the air.

In figure 8, diagram 2, the results of these lime-mortar tests are

compiled, and for comparison the results of the tests of Portland and natural cement mortar taken from the mixing-box and made during the same period are added. The bar-sand and gravel and standard quartz-sand used in all these tests are shown in figure 7.

Tests have also been made of the concrete as it is actually mixed for use. The test-specimens were 6-inch cubes. The concrete was composed of 1 part Portland cement, 3 parts gravel, and 6 parts broken stone (graded from ¼ of an inch up to 2 inches), and had an average weight of about one hundred and forty pounds per cubic foot. The mortar was composed of 1 part Portland cement and 3 parts gravel, and had an average weight of about one hundred and thirty-three pounds per cubic foot.

In figure 8, diagram 3, the average results of the crushing tests of these cubes are shown. Attention is directed to the excellent results obtained by the use of the gravel. This gravel was sharp and clean and unusually well proportioned.

The following are the percentages of residue on the various sieves:

No. 10 sieve, ... 16.56.	No. 50 sieve, ... 20.30.
No. 20 sieve, ... 32.92.	No. 100 sieve, ... 12.54.
No. 30 sieve, ... 14.78.	No. 200 sieve, ... 1.84.

Percentage passing No. 200 sieve, 1.03.

The residue on the No. 200 sieve and what passed through the sieve was perfectly sharp, clean grit, and not a clay, as is the usual case with gravels.

In connection with the lime-mortar tests shown in figure 8, it may be of interest to quote from a book published in 1780, once in the possession of George Washington. It is entitled "Experiments and Observations Made with a View of Improving the Art of Composing and Applying Calcareous Cements and Quicklime." In the introductory pages, the author, Dr. Byron Higgins, expresses himself as follows:

"As the strength and duration of our most useful and expensive buildings depend chiefly on the goodness of the cement with which they are constructed, I looked to the improvement of mortar as a subject of great importance in this country, particularly where the weather is so variable and trying, and the mortar commonly used is so bad that the timbers of houses last longer than the walls, unless the moldering cement be frequently replaced by pointing. But feel-

ing that many years are requisite for the greatest degree of induration which cementitious mixtures like mortar can acquire, and that the life of man is too short to allow any considerable improvements of them to be derived from such experiments as had hitherto been made, I resolved, in the beginning of the year 1775, to investigate, more closely than I had hitherto done, the principles on which the induration and strength of calcareous cements depend; not doubting that

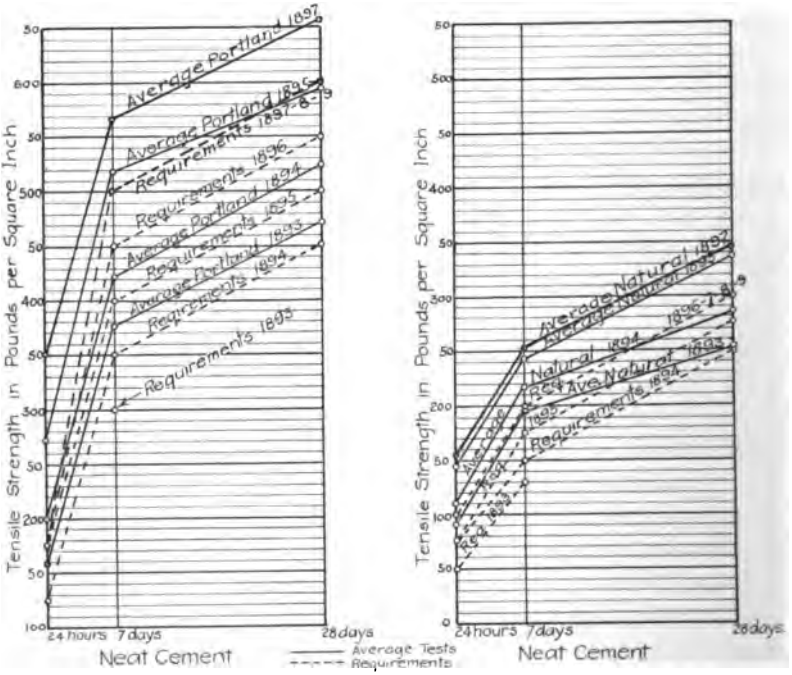


Fig. 9.—Average Tests and Requirements.

this would lead me, by an untried path, to recover or to excel the Roman cement, which in aqueducts and the most exposed structures has withstood every trial of fifteen hundred or two thousand years."

In 1859 John Grant began his celebrated tests of the cement used in the construction of the Southern Main Drainage Works of London. Prior to this year Roman cement was, with few exceptions, the only cement used for the inverts of the London sewers, the arches being set in blue lias lime.

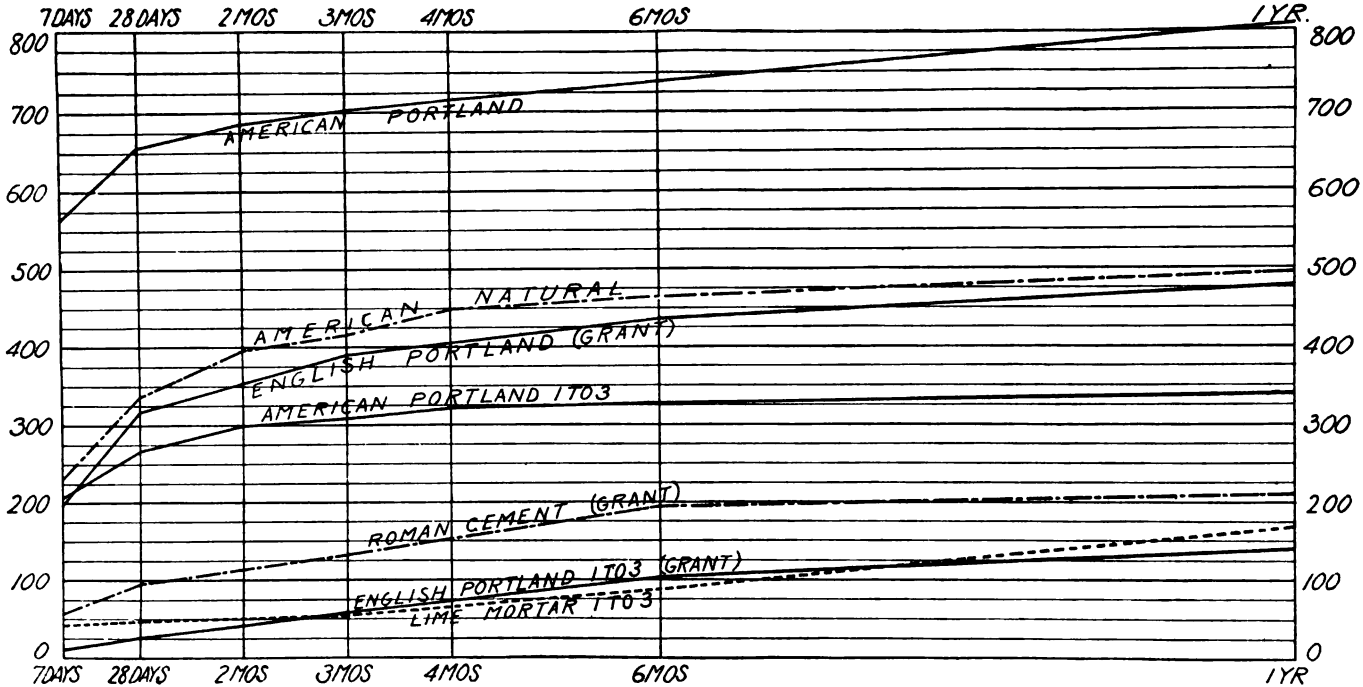


FIG. 10.—COMPARISON OF LIME MORTAR WITH CEMENT OF 1860–65 AND CEMENT OF 1897.

The specifications for this work required that Portland cement should be of the best quality, finely ground, weigh 110 pounds per imperial bushel, and maintain a breaking load of 400 pounds on an area of 2¼ square inches, at the end of seven days, six days in water —equivalent to about 178 pounds per square inch.

The specifications of the city of Philadelphia in 1889 required Portland cement to be of the best quality, finely ground, weigh 112 pounds per imperial bushel, and develop a tensile strength of not less than 275 pounds, or more than 400 pounds, at the end of seven days, six days in water.

Since the establishment of the laboratory, in 1892, the city requirements have been gradually raised each year, as was shown by the average results of the tests to be advisable.

In figure 9 it will be noticed that the average results of the tests each year exceeded the requirements for that year. I have shown on several occasions that the increase in the requirements each year has been accompanied by a decrease in the price of the cement, and I can not emphasize too strongly the fact that to-day the city is using cement at least fifty per cent. stronger, and from ten to twenty per cent. cheaper, than it was when the laboratory was first established.

In diagram, figure 10, I have plotted the average results of the tests of Portland and natural cement used in the city in 1897, the tests of lime mortar, which agree closely with those given by Vicat in 1818, and the results of the tests made by John Grant in the years from 1860 to 1865.

It will be noticed how much superior the cement of to-day is to that used in Grant's time and to the lime mortar described by Vicat and Higgins. Whether the same superiority will be true of the cement at longer periods of time, only time will tell.

It is for this reason that the results of the five- and ten-year tests of the present high-testing cement will be so valuable. Until these results are obtained, we should withhold our judgment as to the merits of these cements.

DISCUSSION.

THE PRESIDENT.—It is well accepted now, is it not, that the personal equation is a very important one in cement tests?

MR. HUMPHREY.—In my opinion, the personal equation is the all-important factor; nothing plays a more important part in testing cements. No matter how conscientious, careful, or intelligent the one who makes the tests may be, it is not possible to obtain accurate results. Thus far no satisfactory solution of this vitally important problem has been found. Various mechanical appliances have been devised for saving labor and for minimizing or eliminating the personal equation, but they have failed to accomplish their purpose. Cement, of all the materials used in construction, is most affected by environment, and requires the greatest care and skill in its manipulation in testing. Each sample must be treated according to its own peculiarities. It is in mixing and molding cement that the effect of the personal equation is most noticeable. An experienced person mixing and molding by hand can tell, by the way the cement acts or feels, whether it is receiving proper treatment, and can govern himself accordingly. In mechanical mixing- and molding-devices it is impossible to tell what is taking place until the operation of mixing or molding is complete, and, therefore, all cements of the same class must be treated alike. Hand mixing permits the exercise of judgment, and for this reason is superior to mechanical mixing. Testing cement is quite simple so far as the methods are concerned, but it is in the execution of these methods and in the interpretation of the results of the tests that the difficulties arise. It is only after years of careful study and actual experience with all grades of cement that a person becomes competent to pass judgment on the comparative merits of cements. The personal equation naturally becomes less prominent with large experience and careful observation.

JAMES CHRISTIE.—When an extra strong and heavy concrete is required I have for many years used a mixture in which a proportion of cast-iron cuttings is incorporated. The composition is as follows:

Cement mortar,	1 part.
Slag or stone,	4 parts.
Cast-iron cuttings,	2 parts (by weight).
One lb. sal-ammoniac to 50 lbs. iron.	

This concrete weighs 210 to 220 pounds per cubic foot, and tested in 6-inch cubes stands the following crushing loads per square inch of surface:

Without sal-ammoniac after	48	hours,			1200 lbs.
" " "	120	"			1600 "
" " "	240	"			1900 "
With " "	120	"			3000 "

The same concrete, without the iron addition, stands about 500 pounds after twenty-five days. The influence of the sal-ammoniac shows the advantage of binding the mass by internal rusting.

EDGAR MARBURG.—I would like to say a few words relative to the testing of concrete. A considerable number of tests on stone and cinder concrete was recently made under my direction in the Department of Civil Engineering of the University of Pennsylvania, by Mr. J. H. Stitzer, Jr. These tests were undertaken partly for the determination of the relative strength of different mixtures, but more especially to investigate the influence of different conditions of bedding.

It is the practice in some testing laboratories to use thin layers of molder's sand, top and bottom, with a view to getting even bearing surfaces. The use of plaster-of-Paris is more common. In the present tests three methods of bedding were used:

1. Universal-jointed metal bearing plates, applied directly to the specimen.
2. The same bearing plates with intervening layers of plaster-of-Paris, top and bottom.
3. The same plates with intervening layers of molder's sand, top and bottom.

The results showed that the first method of bedding gave average values from fifty to one hundred per cent. higher than the third, while the second method gave intermediate values. The differences were more marked with the stone concrete than with the cinder concrete.

No special precautions were taken toward securing a better finish than that obtainable by the use of an ordinary trowel.

In reference to the testing of paving brick, it is now generally recognized that the impact or rattler test is the only one of real importance. There is much difference of opinion, however, as to the best methods of making this test, and the results obtained are often most erratic.

A new impact machine, embodying some novel and promising features, has recently been designed by Mr. Gomer Jones, City Engineer of Geneva, N. Y. In this machine the bricks are held securely clamped around the inner periphery of the barrel, with the edges exposed, as in an actual pavement, which are acted upon by a charge consisting of cast-iron cubes. The effect produced is one both of impact and abrasion, the former somewhat similar to the chipping effect from horses' hoofs upon the pavement.

The chief merits of this machine seem to be: (1) That it simulates actual conditions of service more closely than the methods heretofore used; (2) that it will probably give more uniform and more easily standardized results; (3) that specimens of different manufacture may be readily tested at a single operation, with results that are truly comparative.

THE PRESIDENT.—Which of the cements have the tendency to expand in setting? Some of them have that peculiar quality.

MR. HUMPHREY.—During the process of hardening, cements sometimes expand or increase in volume; this is particularly noticeable in natural cements, and to a less degree in Portland cements. In Portland cements it can be attributed to a lack of seasoning or incorrect proportioning of the raw materials used in making the cement. In natural cements it is principally due to "freshness"—*i. e.*, lack of seasoning. The greatest expansion is found among a class of natural cements which are designated "magnesium."

This expansion shows itself in the neat cement briquettes, and produces a swelling or enlargement of the briquette, quite frequently accompanied by cracking and checking. The effect of expansion on neat cement briquettes is well illustrated in the briquettes shown on page 188. Sand briquettes, unless the force be considerable, scarcely ever show expansion.

THE PRESIDENT.—They were very particular in getting an expanding cement for the Washington Monument.

MR. HUMPHREY.—In a neat-cement briquette the mass is compact, and has comparatively few voids; the expansive force produces visible cracks and checks. Sand briquettes, or the cement mortar and concrete possessing a greater proportion of voids, the expansive force causes the briquette to become more dense without producing visible cracks or checks.

L. Y. SCHERMERHORN.—Do not your experiments encourage the use of rapid-setting cements?

MR. HUMPHREY.—The specifications of the city of Philadelphia require Portland cement to develop its initial set in not less than thirty minutes, and natural cement to develop initial set in not less than ten minutes and hard set in not less than thirty minutes. Quick-setting cement is required only where the conditions are such as to make it necessary.

It has been my experience that quick-setting cements are generally slower in hardening than slow-setting cements, for this reason: I find that when a quick-setting cement is used, it is frequently retempered before going into the work. This retempering impairs the strength of the cement and greatly reduces its hardening qualities. Hence, when the condition of the work does not interfere, slow-setting cements are to be preferred.

WILLIAM COPELAND FURBER.—I would call attention to a fact—clearly shown on Mr. Humphrey's diagram (see Fig. 8)—which deserves to be better known: that is, the great increase in the strength of mortar due to the use of gravel in the place of bar sand. In my own tests of mortar I have obtained on short time tests results from fifty to seventy-five per cent. higher with gravel than with bar sand, the gravel used being known on the Philadelphia market as "Jersey" or "Pea Shore" gravel, which contains little if any more silt or mud than the bar sand, as shown by solution tests.

Many specifications, and particularly building specifications, call for bar or river sand, which would indicate that the superior qualities of gravel for mortar making are not recognized. This superiority is due, I think, to the better assortment of sizes of the grains, permitting a closer filling up of the void in the mass. Cement tests made with sharp, clean gravel will usually give higher results than those made with standard quartz.

MR. HUMPHREY.—It is quite true that the value of the results of the tests of gravel and cement, which are shown in the diagram, can not be fully appreciated from a casual examination.

The great superiority of gravel over bar sand deserves to be more generally known. The tests shown in the diagrams were obtained from what is known as "Jersey gravel," which, as has been previously stated, was of remarkably fine quality.

In the excavations for the Pennsylvania Avenue Subway a bank gravel was encountered. This was subjected to careful tests, and was subsequently used extensively in concrete and mortar for rubble masonry.

The gravel gave the following residues on the various sieves:

No. 10 sieve,	38.38 per cent.	No. 50 sieve,	9.24 per cent.
" 20 "	30.02 " "	" 100 "	4.98 " "
" 30 "	13.92 " "	" 200 "	1.98 " "

Percentage passing No. 200 sieve, 1.39 per cent.

Notwithstanding the fact that the residues on the fine sieves were practically all clay, and the coarser particles of the gravel were coated with clay, the results of the tests were fully as high as those obtained by the use of "Jersey gravel."

When it was necessary to cut into mortar or concrete made from the former gravel, it was found to be exceedingly hard, and had the appearance of conglomerate rock.

Gravel is especially suitable for use in concrete, or in mortar for laying rubble masonry. Where close joints are necessary, as in brick or ashlar masonry, etc., a mortar made from gravel is unsuitable, on account of the presence of large pebbles in the gravel.

E. M. NICHOLS.—Have you made any tests of cements into which lime was added?

MR. HUMPHREY.—I have never made any tests to determine the effect of additions of lime to cement mortar or concrete. I believe it is the practice abroad, particularly in Germany, to add certain proportions of slaked lime to the cement mortar or concrete. It has been found that the addition of slaked lime makes the mortar rich and work smoothly, making it possible to spread it. This would not be the case with ordinary cement mortar, which works "short."

Nearly all of the cements from which the tests shown in the diagrams were compiled were treated cements, or cements to which calcium sulfate had been added. The use of this body for regulating the time of setting is general. The well-known brands of German cements all contain a small proportion of calcium sulfate. In addition to making the cement slow-setting, it increases the early strength, and renders the cement brittle. This brittleness is particularly noticeable in the long-time tests of neat-cement briquettes, where there is usually a decided falling-off in tensile strength; there is no such loss of strength in the sand briquettes, or when the cement is tested in compression. In my opinion, the proper way to test cement is in compression. The briquettes required for tension tests are conveniently made, and the cost of the apparatus for testing them is comparatively small. Test specimens for crushing tests are, on the contrary, more troublesome to make, and the machine for testing them is quite expensive, requires power, and occupies much more space. Compression tests are not, therefore, nearly so practical as the tension tests. In permanent laboratories it is practicable to make such tests, and they obtain a much better idea of the value of a cement than the tests for tensile strength.

COMMUNICATIONS PRESENTED AT A SPECIAL MEETING, HELD MARCH 25, 1899, TO DISCUSS THE PRESENT PROBLEM OF THE WATER-SUPPLY OF PHILADELPHIA.

WATER-SUPPLY OF PHILADELPHIA.

JOHN C. TRAUTWINE, JR.

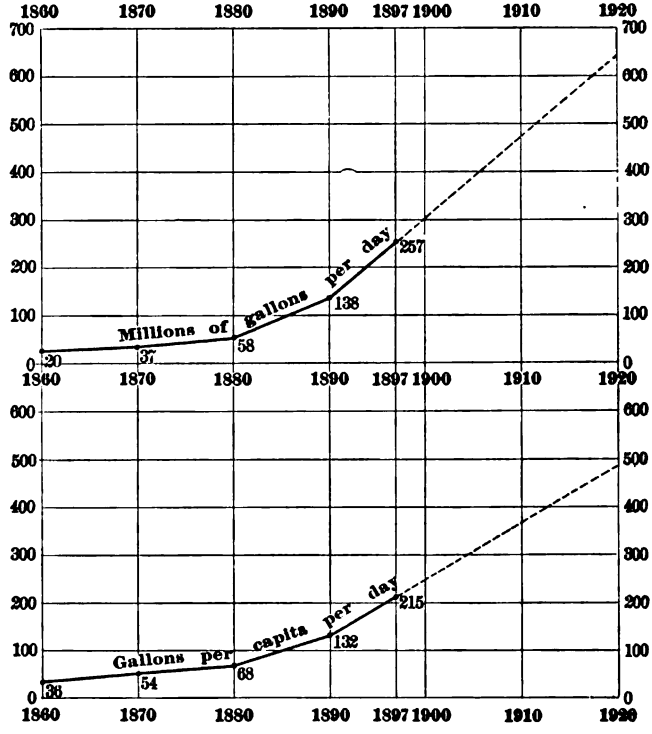
An intelligent discussion of the water-supply of Philadelphia presupposes the possession of information respecting the existing conditions of that supply. I may, therefore, with propriety set before you certain of the fundamental facts respecting our supply, although my position as Chief of the Bureau of Water forbids my entering into the discussion proper. In water-supply, as in other manufacturing business, the question of first importance is that which concerns the quantities handled. I therefore ask your attention to the following diagram, which shows the total and the per capita consumptions in each tenth year from 1860 to 1890 inclusive, and also that in 1897:

Tabulated, the corresponding figures appear as follows:

		Average Daily Consumption of Water. Gallons.	
Year.	*Population.*	*Total.*	*Per Capita.*
1860, ...	565,529	20,398,198	36
1870, ...	674,022	36,692,625	54
1880, ...	847,170	57,698,719	68
1890, ...	1,046,964	137,736,703	132
1897, ...	1,200,000	257,500,000	215

The popular mind probably has no conception of the volumes represented by the figures giving our average daily pumpage; and even the engineering mind may be surprised to learn that the average daily pumpage of 1897, amounting to more than two hundred and fifty million gallons, is equivalent to a prism 100 feet square and 3300 feet long. Such a body would fill Market Street from house-line to house-line (100 feet) to a depth of 100 feet, and would reach from the Delaware to beyond Seventh Street. The average daily pumpage of 1898 (275,000,000 gallons) would, of course, extend farther west, and that of 1899 would probably reach to Ninth Street.

Perhaps the most important feature of this table and diagram is the light they throw upon the *rate of increase* of consumption. The



Consumption of Water, Total and per Capita, in Philadelphia.

increase in the average daily consumption, in the several periods shown, was as follows:

	Increase in Average Daily Consumption of Water. Gallons.	
Period.	*Total.*	*Per Capita.*
1861–70, ...	16,294,429	18
1871–80, ...	21,006,094	14
1881–90, ...	80,037,984	64
1891–97 (7 years), ...	119,763,297	83

The remarkable increase in the rate of increase, since 1880, or, perhaps, more properly, since 1885, seems to be explainable, in part at least, by a regulation of the Board of Health, which went into effect about 1885, requiring the abandonment of all cess-pools and the sub-

stitution of outside water-closets. Unfortunately, the form introduced was an extremely wasteful one. In the foregoing diagram the dotted line, in each case, extending from 1897 to the limit of the diagram (1920), shows the figures which would be reached if the present rate

TWO HUNDRED AND FIFTY MILLION GALLONS.
(One hundred feet square, 8300 feet long.)
Market Street, Looking East from Seventh Street to Delaware River. Average Consumption, Philadelphia, 1898, 275 Million Gallons per Day.

of increase were maintained. These figures are approximately as follows:

	AVERAGE DAILY CONSUMPTION OF WATER. GALLONS.	
Year.	*Total.*	*Per Capita.*
1900, ...	300,000,000	245
1910, ...	470,000,000	360
1920, ...	640,000,000	480

Stupendous as these figures appear, it must be borne in mind that they represent a conservative assumption—viz., that the present rate

of increase of consumption continues unchanged; whereas our past experience teaches us that the rate of increase does not remain constant, but itself increases. Unless, therefore, some means are adopted to control the rate of increase, we must inevitably reach even more startling figures as we march into the coming century.

The foregoing estimates of consumption are based upon the plunger displacements of the pumps, after making what are supposed to be proper deductions for sources of error, such as the inevitable slip and the short stroke in the case of engines without fly-wheels. Notwithstanding these allowances, it is altogether probable that the figures given for the consumption are somewhat exaggerated; but that they do not grossly misrepresent the actual pumpage may be inferred from the fact that, the summer flow of the Schuylkill being approximately known, water would be flowing over Fairmount dam at all times if the actual pumpage were very much less than that given in the foregoing tables and diagram. Our observations, in the case of mains exposed for excavations, etc., lead us to believe that no very great loss takes place through leaky mains. It has been suggested that the building of three of our largest reservoirs (Queen Lane, East Park, and new Roxborough) during the last dozen years may account for the large increase of consumption during the same period; but here, too, the evidence of material leakage is negative. A year ago, Queen Lane reservoir, after being relined with asphalt, was found to be losing, when full, not more than about half a million gallons per day by leakage. East Park gives every reason for believing it to be practically tight; and the new Roxborough reservoir, owing to excess of demand above supply, has never yet been filled. Indeed, during most or all of 1898 it was entirely cut off from the distribution and from pumpage, in order to prevent it from being entirely emptied.

Finally, observations of the consumption in many separate properties give us abundant reason for relying upon the substantial correctness of the Bureau's figures respecting consumption. Even if gross exaggeration took place, it is altogether probable that this exaggeration bears no greater ratio to the whole consumption now than during earlier years. It, therefore, does not affect the deductions drawn as to the proportional *rate of increase* and the *increase* of that rate.

Next in importance to the quantity of water to be handled are the

means provided for handling it. During the last four years no additions have been made to our pumping or distributing machinery, and the service is in a condition bordering upon water famine, acute distress having been already experienced in many localities, notably in portions of Germantown. The reason for the failure of the Bureau to make the necessary extensions is found in the following table, which shows our annual estimates for extensions for the years 1896, 1897, and 1898, respectively, and the amounts left in the appropriation bills for that purpose by the Finance Committee:

	Estimates.	Appropriations.
For 1896, ...	$2,484,150	0
For 1897, ...	3,339,450	0
For 1898, ...	3,735,050	0

I quote as follows from my annual report for 1898:

"Year after year, through you, I have warned Councils of the condition of our works, and have appealed for the means necessary to avert disaster. Year after year, my warnings and appeals have been disregarded.

"During my administration, not one cent has been appropriated for extensions of the works, until, within the past year, a few trifling amounts have been granted, barely sufficient to prevent absolute water famine in one or two cases, but leaving entirely untouched the great and urgent needs of our system as a whole.

"Every effort has been made to meet the conditions with the inadequate means provided. Our boilers and engines are strained to the utmost night and day, and in some cases disabled; there is no opportunity for thorough repairs; we dare not stop pumping during seasons of muddy water; in spite of all manner of pitiful expedients, we are compelled to cut off our reservoirs from the distribution in order to keep them from being entirely emptied; and from all sides come well-grounded complaints from citizens who pay for a water-supply, but do not get it."

The following comparison between the engineering forces of the water departments in New York and in Philadelphia will be of interest from an engineering standpoint:

NEW YORK GENERAL ENGINEERING FORCE.

Bureau of Chief Engineer.

	Per Annum.
Chief engineer,	$7,000
First assistant engineer,	5,000

Aqueduct Repairs, etc.

Transitman,	1,500

Laying Croton Pipes.

Assistant engineer,	3,600
Transitman,	1,500
Leveler,	1,200
Draftsman,	1,350

Water-main Fund.

Consulting engineer,	5,400
Assistant engineer,	3,600
Assistant engineer,	3,600
Transitman,	1,500
Rodman,	1,200
Rodman,	1,000
Transitman,	$1,400
Draftsman,	1,500

Croton-water Fund, Construction and New Surveys.

Topographic engineer,	3,000
Assistant engineer,	3,000
Two assistant engineers at $2,400,	4,800
Assistant engineer,	2,000
Two assistant engineers at $1,800,	3,600
Transitman,	1,500
Draftsman,	2,000
Three draftsmen at $4.50 per day,	4,050
Two levelers at $1,400,	2,800
Two levelers at $1,200,	2,400
Two rodmen at $1,200,	2,400
Two rodmen at $1,000,	2,000
Chainman,	900

Total, thirty-six men, $74,800 per annum.

Croton Aqueduct Commission.

Chief engineer,
Three division engineers,
Eleven assistant engineers,
Three transitmen,
Two levelers,
Six rodmen,
One chainman,
Twenty-three axmen,
Four draftsmen.

Total, fifty-four men.

PHILADELPHIA.

	Per Annum.
Chief of Bureau,	$6,000
Chief draftsman,	1,800
Two draftsmen at $1,000,	2,000
One draftsman,	900
Three rodmen at $2.50 per day,	2,250
Assistant in charge of distribution,	2,000

Total, nine men, $14,950 per annum.

In this connection I venture to quote again from my annual report for 1898:

"WHAT THE ENGINEERING FORCE SHOULD BE.

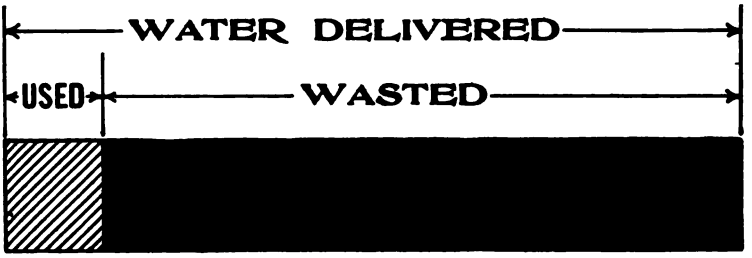
"The proper development of a large water-supply requires that it be placed in the hands of a sufficient force of intelligent, well-informed, and skilled persons, capable of understanding the present

and estimating the future conditions and needs of the service. This force must be given every possible facility for investigation and experiment, and must not only be unhampered by capricious legislative interference, but must be assured of intelligent, hearty, and loyal legislative support. Under these auspices an harmonious plan for the development of the system, for many years in advance, should be mapped out, adopted, and followed; and every proposition for extension or other change should be carefully studied in the light of this plan and made to conform to it."

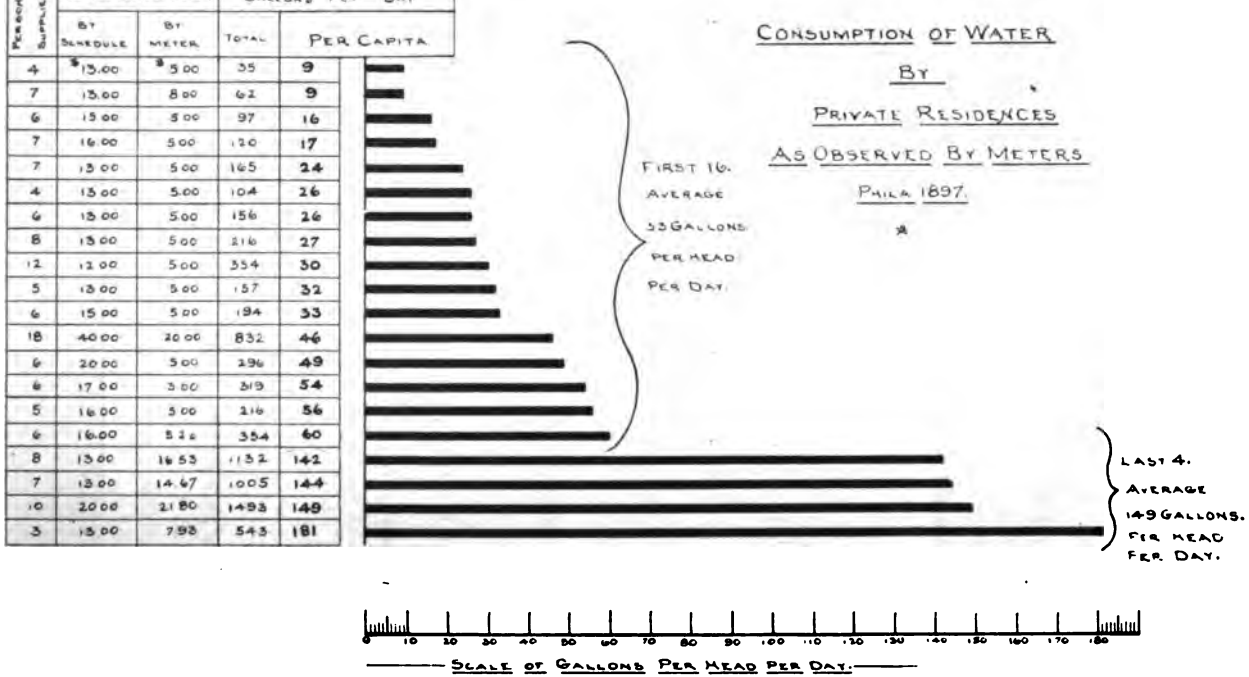
Scarcely less startling than the enormous quantities of water which our waterworks are strained to the utmost to furnish is the fact that more than half of this quantity is absolutely wasted, benefiting no one—not even those who waste it. And it is perhaps equally important to note that this waste is perpetrated by a small fraction—hardly more than one-fifth—of our population, as witness the following results of investigations by the Bureau respecting the quantities used and wasted by private residences:

TWO INTERMEDIATE STREETS WITH ONE HUNDRED AND FORTY-TWO MODERN SEVEN-ROOM TWO-STORY DWELLINGS.

Number of appliances,	Total,	782
	Leaking slightly,	22
	Turned on continually,	32
Gallons per twenty-four hours,	Total,	119,800
	Used,	16,120
	Wasted,	103,680
Gallons per capita per twenty-four hours,	Total,	222
	Used,	30
	Wasted,	192
Percentage of total,	Used,	13½
	Wasted,	86½



Persons Supplied	Annual Cost of Water		Gallons Per Day	
	By Schedule	By Meter	Total	Per Capita
4	$13.00	$5.00	35	9
7	13.00	8.00	62	9
6	13.00	5.00	97	16
7	16.00	5.00	120	17
7	13.00	5.00	165	24
4	13.00	5.00	104	26
6	13.00	5.00	156	26
8	13.00	5.00	216	27
12	12.00	5.00	354	30
5	13.00	5.00	157	32
6	15.00	5.00	194	33
18	40.00	20.00	832	46
6	20.00	5.00	296	49
6	17.00	5.00	319	54
5	16.00	5.00	276	56
6	16.00	5.26	354	60
8	13.00	16.53	1132	142
7	13.00	14.47	1005	144
10	20.00	21.80	1493	149
3	13.00	7.98	543	181


Consumption of Water
By
Private Residences
As Observed By Meters
Phila 1897.
First 16. Average 53 Gallons per Head per Day.
Last 4. Average 149 Gallons. per Head per Day.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Scale of Gallons Per Head Per Day.

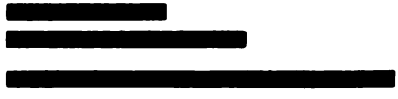
Such investigations as these certainly justify the statement that more than half of all the water pumped is wasted.

The following diagram, which shows the result of the investigation of the consumption of water in twenty dwellings, confirms the statement that this waste is perpetrated by a small fraction of our people, this small fraction thus victimizing the careful consumers, who are in an overwhelming majority. It illustrates also the inequities of the system of charging for water by the year. The first sixteen residences averaged 33, the last four averaged 149, and the last of all consumed 181 gallons per head per day, and pays $13.00 per annum, whereas one which took only 46 gallons per head per day pays an annual water bill of $40.00. Two other consumers, each paying $20.00 annually, took, respectively, 296 and 1493 gallons daily (total).

The result of wasting more than half of all the water pumped was summarized as follows in a paper which I presented to this Club, October 1, 1898:

"If the waste, or even the major part of it, were stopped, the capacity of our works would be practically doubled, and there would be plenty of water for all. The cost of installation of filter plants, or that of bringing water from a distance, would be cut in two. Even without the adoption of means for purifying the water, the quality of that furnished would at once improve, for pumping could then be stopped during seasons of muddy or coal-polluted water, and the water in the reservoirs would have longer time for sedimentation. The minimum flow of the Schuylkill would once more greatly exceed the city's maximum draft upon it, the city's annual conflict with the Schuylkill Navigation Company would be avoided, and the specter of the city's acquisition of that company's properties would be once more suppressed. Finally, the improvement and development of the supply would be brought well within the city's own means."

The following comparative tables show the effect of waste upon the cost of putting our works in proper order, and of installing means for the improvement of the quality of the water. The first of these gives the figures as related to the entire supply. The second, which refers only to the West Philadelphia district, shows a case where the contrast is even more striking.

For Water Used.	Extensions, . 1,000,000 Filtration, . 2,500,000 Total, . . $3,500,000	
For Water Used and Wasted.	Extensions, . 5,000,000 Filtration, . 7,500,000 Total, . . $12,500,000	

Estimates of Cost of Improvement of Water-supply in West Philadelphia for 1900.

	Water Used.	Water Used and Wasted.
Maximum per day, ...	Gallons. 15 million.	Gallons. 45 million.
Improvements Required.		
Additional pumps, ...	$0	$75,000
Annex to engine-house, ...	25,000	40,000
Condenser, ...	6,000	6,000
Additional pumping main, ...	0	92,000
Additional supply mains, ...	0	186,000
Additional reservoir, ...	0	500,000
Total, exclusive of filtration, . . .	$31,000	$899,000
Filtration plants, ...	250,000	750,000
Sedimentation basins, ...	0 (?)	200,000 (?)
Total cost of installation, ...	$281,000	$1,849,000
Annual expense of operation of filters, at $4.00 per million gallons, ...	$20,000	$60,000

In making these comparisons I have assumed that the cost of installation and of operation of filtration plants would be proportional to the consumption; whereas it is almost certain that, in our case, the cost would increase more rapidly than the quantity to be filtered. On the Schuylkill side, at least, the difficulty of finding suitable sites for slow filter beds would be enormously increased if we were to continue wasting water as at present. The provision necessary for sedimentation would also be greatly increased.

In the first of these two comparisons (that covering the entire city) I have included, for extensions, $5,000,000 in the case of water used and wasted, and $1,000,000 in the case of water used; but in this connection it is important to notice that our works, exactly as they are, are abundantly able to furnish all the water that could possibly be used and enjoyed by a city of twice the size; and the $1,000,000 set down for extensions is required simply for such extensions as will bring the whole system to a condition of nearly uniform efficiency and make needed repairs; whereas the $5,000,000 for extensions in the case of water used and wasted is absolutely needed, and needed at once, if we are to be enabled to supply the enormous quantities wasted, in addition to those used. One million dollars expended for extensions in the case of water used would give not only an ample supply for the entire city, but also a surplus of pumping capacity of about 100 per cent.; while $5,000,000 expended for extensions in the case of water used and wasted would barely meet the present demands.

THE WATER PROBLEM IN PHILADELPHIA.

EDGAR MARBURG.

WE are met this evening to do our part, as engineers and as citizens of Philadelphia, in an effort to bring about a rational solution of what has come to be known as the water problem. Aside from the simple question of finance and the complex one of "practical" politics, the problem is purely an engineering one. It is not necessary, however, that one should be versed either in finance or in engineering, much less in machine politics, to arrive at sound general conclusions—that is, to discern a straight, clear way through the maze of visionary, corrupt, or quack schemes that have been proposed or "promoted" in endless variety and number. Disinterested honesty and plain, common sense are the only real essentials.

To squarely meet the issues as they stand to-day, what are the facts?

1. That the net revenues to the city from its water-works are about one million dollars per annum.

2. That for the past several years, practically no appropriation has been allowed for extensions, however urgent the need and the demand.

3. That for the present year the estimates for bare maintenance—that is, current necessities—have been scaled down to sums known by experience to be absolutely inadequate.

4. That, through lack of restrictive measures against wanton waste, the average daily pumpage has reached the stupendous aggregate of 275,000,000 gallons, or about two hundred and thirty gallons for every man, woman, and child in the city of Philadelphia.*

5. That most of the pumping machinery must be kept in perpetual operation, in its ceaseless race against impending water famine.

6. That, through accident to the machinery, a crisis may be reached at any moment, to cause widespread suffering in our community.

7. That some districts are feeling even now the infliction of an inadequate water-supply and insufficient pressure.

8. That, with the present extravagant rate of consumption, mere sedimentation for a limited period is impracticable.

9. That, through lack of timely measures for effective purification, our city is now scourged by a visitation of typhoid fever more appalling in its death-rate than any experience of the past.†

10. That the earnest recommendations and appeals of the Bureau of Water, renewed for these many years with unfailing regularity, are cast to the winds. That this bureau, instead of receiving proper aid in carrying out the sound policies it has proposed, finds its energies largely wasted in vain attempts at making serious responses to absurd inquiries and formal reports on impracticable schemes.

These are the salient facts in the situation as it exists to-day. The remedy may be summed up in a dozen words. *Let the public and the press unite in loyal support of the Water Bureau.* If the officials of

* This estimate is based on an assumed present population of 1,200,000. According to the census of 1890, the population of Philadelphia was then 1,046,964.

† The highest death-rate in Philadelphia from typhoid fever during the past thirty-eight years (for which records are available) was reached in 1865, at the close of the Civil War. The deaths numbered 124 per 100,000 of population. In 1876, the year of the Centennial, the number was 92. During the first twelve weeks of the present year, to March 25th inclusive, there have been 444 deaths, or at the rate of 1924 per annum for the entire population. Estimating the latter at 1,200,000, the deaths per 100,000 number 160 per annum, or 30 per cent. greater than the average death-rate for the year 1865—the worst on record. It is to be especially observed, however, that the average of a twelve weeks' period is here compared with that of an entire year. It is, perhaps, not reasonable to assume that the present high death-rate will be long maintained.

this bureau should prove themselves incompetent or faithless to their trust, the officials should be changed. The principle itself remains unaffected. In the campaign against recalcitrant members of City Councils, let the watchword be, "Support our Engineers." Let matters of engineering be entrusted to the unhampered control of engineers. No profession has shown itself more worthy of trust in matters coming within its sphere. Let laymen not presume to dictate policies or to obtrude advice in matters purely professional. Let Councils confine themselves to the honest discharge of their own special functions—that of providing ways and means for the speedy and effective execution of such measures as are recommended by the engineers.

Summed up in brief, what does the Bureau of Water propose in the present exigency?

First.—Adequate appropriations for placing its plant in a state of uniform efficiency.

Second.—Measures for the restriction of wanton waste.

Third.—The installation of filtration plants.

Concerning the first proposition there can be no division of honest sentiment. Its reasonableness will be admitted by every right-minded member of this community. It may be dismissed off-hand on its merits, without argument.

The second and third propositions can not be treated separately. We need no training as engineers to recognize the folly of plunging out upon an elaborate scheme of filtration, unaccompanied by measures for the restriction of our present wholesale waste. Referring first to filtration, it is probably true that the overwhelming proportion of our population have come to recognize its imperative need. This is not the time to discuss the relative merits of various systems. Such questions may be left with confidence to the proper officials, who propose to avail themselves of the absolutely disinterested council of leading experts. The problem of filtration may well be dismissed with these general statements.

It is against the evil of reckless waste that the campaign of popular education should be especially directed, and it behooves us, as engineers, to be leaders, not weak-kneed followers, in this campaign. As engineers, familiar, if only in a general way, with the experiences of other cities, we know that the introduction of meters is the only

proper solution. The proposed substitution of automatic valves for appliances now in common use, especially in connection with hopper-closets, though an encouraging step in the right direction, does not strike at the root of the evil. The present opposition of the public and of the local press against water-meters is but a repetition of the history in many other cities where meters have come to be recognized as the helpful agencies they really are. The oft-repeated popular cry that water should be as free as air and sunlight is as fallacious as many other phrases that captivate the unthinking ear. Water is free to him alone who fetches it with pail in hand from its place in nature and sets no value on his time and labor.

Making all reasonable allowance for errors in the computation of pumpage, for evaporation and seepage from the reservoirs, and for leakage in the distributing system, the stubborn fact remains that from one-half to two-thirds of our so-called consumption is chargeable to the most reckless waste. It is not my purpose to present elaborate arguments and statistics in support—I will not say defense—of meter systems. The experience of the numerous municipalities in which such systems have been adopted all point to the same general conclusions. I propose, therefore, to direct attention merely to a few leading facts, not for the information of engineers, but as an appeal to thoughtful laymen.

The adoption of meters will meet with immediate response in the reduction of waste. With a sufficiently comprehensive system, our consumption will be reduced one-half or more. The reckless consumer must reform, or pay the penalty of his own folly. His waste will no longer fall as a tax upon his more prudent townsmen.

Decreased consumption means a proportionate saving in coal-bills and numerous other operating charges. The capacity of the distributing system will be correspondingly increased. In low-pressure districts, increased pressure will result without the purchase of additional pumps. Pumps now driven night and day may be thrown out of service and kept in reserve for contingencies.

The fixing of water-rates will be changed from mere guesswork to a system equitable to all consumers. With equal net revenues to the city, the cost to the average consumer will inevitably be reduced.

Lastly, if waste is to proceed unchecked, the outlook for filtration seems well-nigh hopeless,—both by reason of its enormously increased

cost and because of the then urgent need for extensions in all directions.* With restricted waste, the existing reservoirs will probably suffice for at least preliminary sedimentation preparatory to filtration.

If the foregoing facts were fully appreciated by the public, the present wide-spread opposition to the meter system would, doubtless, quickly melt away.

The objections urged against meters with some sound of reason may be grouped under three principal heads:

First.—That a charge for water according to consumption would cause the poorer classes to stint themselves in its use, discourage cleanliness, and prove prejudicial to the general health and comfort of the community.

The answer is: Prescribe a fixed minimum charge regardless of quantity actually used, provided the latter does not exceed a certain stipulated, but amply liberal, allowance, and impose an additional pro rata charge on extra consumption only. The per capita allowance may be fixed at will, the main contention being that *some* limit should be set.

Second.—That since water-rents in Philadelphia are borne by property owners, not by tenants, the former would be held liable for waste or leakage which they are powerless to prevent, and that innumerable disputes and law-suits would be the outcome.

The change to a system, exempting the owner and placing the tax wholly on the tenant, however rational, would meet with determined opposition and could not easily be brought about. An obvious solution, in line with the present system, would be to have the lease so drawn that the owner assumes the fixed minimum charges and the tenant is held responsible only for surplus waste.

* Estimates from the "Annual Report of the Chief of the Bureau of Water" (1898), J. C. Trautwine, Jr., Chief of Bureau:

	Without Meters.	*With Meters.*	
Extensions.....	$5,000,000 (urgent)	$1,000,000	(for developing full capacity in excess of need).
Filtration Plants,	7,500,000	2,500,000	
Meters.....		1,000,000	(for the partial sytem proposed).
Totals.....	$12,500,000	$4,500,000	

Thus, the estimated increased cost, without meters, is $8,000,000. Moreover, with unrestricted waste, future extensions will have to be continued on the same lavish scale as in the past, extending also to the filtration plants.

Third.—That meters would affect the manufacturing interests unfavorably.

But, as has frequently been pointed out, the meter does not fix the rate, but simply registers the quantity. Without entering upon the merits of any particular line of policy, water might be furnished to the manufacturers at discriminating rates or even gratis, if deemed expedient. Nevertheless, a reasonable limit should be set even to public bounties, and without the meter the common interests can not be safeguarded against gross abuse in individual cases. Unless the present average rates to manufacturers are entirely disproportionate to their average legitimate consumption, it follows, on the basis of the present net revenues to the city, that a saving will accrue to the average manufacturer, without resort to discriminating rates.

The most significant fact in the history of meters is that wherever they have been allowed to gain a reasonable footing, their merits have become recognized by the public, and that in no instance a backward step has been permitted in their use.

GENERAL DISCUSSION.

THOMAS L. HICKS (non-member) (after referring to the history of the agitation of the water question in Philadelphia, and to the value of reservoirs and pumping facilities):

I desire to say that notwithstanding all objection, there is too much advantage to be derived from meters to brush the question aside upon the ground that water ought to be as free as air. In my opinion, with every house in this town metered, water would be still as free as air, for the proper uses of the people, without unnecessary restriction. During the time that I was a member of Councils I spent nearly three months in going into the question of water-meters, visiting dyeing establishments, morocco dressers, and factories throughout this city that were supposed to be large consumers of water—using water, in fact, in the nature of a raw material. The meter rate of water at that time was sixty cents a thousand cubic feet. This is two cents a ton. Now, I ask what manufacturing industry of the city of Philadelphia would be driven out because it had to pay for water at the rate of two cents a ton? So much for the cost of water. Now as to saving: In one part of the city there were two morocco

leather factories facing each other. I can not recollect the exact figures, but I will give the proportions based upon facts, because I took the records, made the calculations, etc. One establishment employed about fifty men, the other about one hundred and fifty, and each turned out goods in proportion. The smaller establishment paid a bill of $142 per year. The larger paid $45 a year. When meters were put into these two establishments the water-rent of one came down and of the other went up, putting them on an equality, and they were taxed by the meter-measurement exactly alike for each dozen of skins turned out thereafter. Another case came under observation at that time. During the course of the inspection of one establishment it was found that at six o'clock on Saturday night a man who had been using a hose dropped it when the whistle blew, and that the water ran until the mill was opened on Monday morning. It was clearly established they wasted 750,000 gallons of water from Saturday night to Monday morning. Had a meter been in that establishment that would have happened possibly once, but after that the proprietor would take good care to see that the water was turned off. There is a good deal in the story of waste, but I have yet to be convinced that there is quite as much in it as the returns of the Bureau of Water show.

L. Y. SCHERMERHORN.—Is not the restriction of waste in the hands of the Water Bureau?

MR. TRAUTWINE.—Theoretically, yes; but our hands are few and weak, relatively to the immensity of the task. Our force of inspectors numbers nineteen, and the population is about a million and a quarter. True, as I have said, only a small fraction of this population does the wasting for the city; but that fraction is not confined to one district, but is scattered over the whole city, and thus involves perhaps nearly as much labor as if the whole population were guilty of waste. Prior to my administration, attempts at waste restriction by house-to-house inspection were made, but resulted only in temporary improvement. We have, however, recently resorted to it again in the case of the Germantown district, where the shortage in certain districts is very distressing. Intelligent laborers have there been detailed to supplement the force of inspectors, visiting the premises and leaving circulars calling attention to the ordinances of Councils respecting waste of water; but we have not yet been able to estimate

the results of the process. Mr. Fuller, Assistant-in-Charge of Distribution, can give us some particulars on this subject.

ALLEN J. FULLER.—In one district, in which the waste was studied with the aid of the Deacon waste-water detector, we succeeded in having all the fixtures put in good order, and the major portion of the waste stopped; but a reinspection, made about six months later, showed water being wasted at an even greater rate than at the time of the first inspection. At one time half the fines imposed were paid to informers, and under this system much was done in restricting waste; but it was abandoned, I think, by ordinance of Councils. More efficient and perfectly satisfactory means for the prevention of waste have been applied in many cities and towns, and always with the most gratifying results.

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, February 4, 1899.—The Second Vice-President in the chair. Eighty-five members and visitors present.

Mr. P. J. A. Maignen read a paper on "The Problem of Water Purification for the City of Philadelphia."

The subject was discussed by Messrs. Firth, Landis, Easby, Comfort, and Nichols.

The tellers reported the election of W. M. Stine to active membership, O. T. Knight and W. M. Wood to junior membership, J. L. Moyer and B. F. Stradley to associate membership, and the transferring of J. B. Bonner, J. Ogden Hoffman, and J. W. Ridpath from associate to active membership.

REGULAR MEETING, February 18, 1899.—The President in the chair. Fifty-one members and six visitors present.

Mr. J. W. Ledoux read a paper entitled "A Sand-Filter Plant."

The subject was discussed by Messrs. Trautwine, Maignen, Leffmann, Schumann, E. M. Nichols, and Christie.

A "Note upon the Strength of Tubes to Resist Internal Pressure," presented by Mr. L. Y. Schermerhorn, was read by title and referred for publication.

REGULAR MEETING, March 4, 1899.—The President in the chair. Seventy-three members and ten visitors present.

A paper prepared by Mr. Theodore Spencer, on "Some Problems in Telephone Engineering," was read by Mr. P. L. Spalding in the absence of the author.

The subject was discussed by Messrs. Schumann, Leffmann, Hering, Maignen, Fairchild, Merritt, Eglin, and Miller.

REGULAR MEETING, March 18, 1899.—The President in the chair. Sixty-three members and seven visitors present.

Professor J. B. Johnson (non-member) read a paper entitled "The Fruits of Sanitary Science."

The subject was discussed by Messrs. Furber, Hewitt, Ledoux, Marburg, and Merriman.

SPECIAL BUSINESS MEETING, March 25, 1899.—The President in the chair. Seventy-seven members and visitors present.

The meeting was called to discuss the present problem of the water-supply of Philadelphia, and to prepare an address to the public.

Remarks were made by Messrs. Trautwine, Marburg, Webster, Schermerhorn, Fuller, Falkenau, and Maignen, and several invited non-members. On motion, the chair was directed to appoint a committee to prepare a series of resolutions as would adequately express the opinion of the club. The committee, consisting of

Messrs. Schermerhorn, Marburg, Christie, Webster, and Falkenau, reported the following resolutions, which were unanimously adopted:

"*Resolved*, That, in the judgment of The Engineers' Club of Philadelphia, City Councils should take such immediate action as will secure the following results:

"1. The placing of our present water-supply beyond impairment.

"2. That the undue waste of our water-supply should be prevented.

"3. That the initiation of the purification of our present water-supply should be at once undertaken under the ownership and control of the city.

"4. That the detailed methods for securing these physical results should be assumed by the executive department of our city government."

The following resolution was also adopted:

"*Resolved*, That a committee of five members of this Club be appointed by the President to further the carrying out of the intent of the resolutions pertaining to the water-supply of the city of Philadelphia, adopted on this date, with authority to act conjointly with similar committees of other organizations of disinterested citizens."

BUSINESS MEETING, April 1, 1899.—The President in the chair. Sixty-five members and six visitors present.

The President announced that the third-story front room of the Club-house had been fitted up as a billiard-room by private subscription, and was now ready for use of the members.

Mr. Richard L. Humphrey read a paper entitled "A Few Remarks on the Testing Laboratory of the City of Philadelphia."

The subject was discussed by Messrs. Christie, Marburg, Furber, and Schermerhorn.

Mr. Carl Hering read some notes on "Recent Developments in Electrical Engineering."

The subject was discussed by Messrs. Eglin, Livingston, Fuller, Christie, Schumann, and Miller.

The tellers reported the election of Messrs. E. C. Alsop, F. Head, R. A. McKee, and T. Rose to active membership.

REGULAR MEETING, April 15, 1899.—The President in the chair. Fifty-nine members and three visitors present.

Professor Oscar C. S. Carter (non-member) addressed the Club upon the subject of "Coastal Topography."

The subject was discussed by Messrs. Davis, Richards, Hewitt, and Smith.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, February 18, 1899.—Present: The President, the Vice-Presidents, Directors Humphrey, Smith, Evans, Levis, and Souder, and the Secretary.

The Treasurer's report showed balance January 31, 1899, $2248.39.

The resignation of W. C. Kerr was accepted.

Permission was given to the Library Committee to solicit subscriptions and contributions of books to a reference library for the Club.

REGULAR MEETING, March 18, 1899.—Present: The President, the First Vice-President, Directors Humphrey, Ott, Smith, Levis, and Souder; the Secretary and the Treasurer.

The Treasurer reported balance on hand February 28, 1899, of $2593.14.

REGULAR MEETING, April 15, 1899.—Present: The President, the Vice-Presidents, Directors Humphrey, Smith, Evans, and Levis, and the Secretary.

The Treasurer reported balance on hand March 31, 1899, of $2371.94.

The President announced some changes in the personnel of the standing committees of the Board, and read the list as follows:

Finance.—Wm. C. L. Eglin, Henry Leffmann, Minford Levis.

House.—Minford Levis, Wm. C. L. Eglin, Wm. Penn Evans.

Library.—Richard L. Humphrey, E. F. Smith, Wm. Penn Evans.

Membership.—E. F. Smith, Harrison Souder, R. L. Humphrey.

Information.—Harrison Souder, R. L. Humphrey, C. H. Ott.

Publication.—Henry Leffmann, Wm. C. L. Eglin, C. H. Ott.

ADDITIONS TO GENERAL LIBRARY.

FROM THE SMITHSONIAN INSTITUTION.

Annual Report, 1896.
Proceedings and Transactions Nova Scotian Institute of Science, Volume IX.

FROM DEPARTMENT OF THE INTERIOR, WASHINGTON, D. C.

Irrigation Papers Nos. 19 and 20.

FROM THE CITY OF PITTSBURG.

Report of Filtration Commission, 1899.

FROM THE GOVERNMENT PRINTING-OFFICE, WASHINGTON, D. C.

Exports Declared for the United States, September, 1898.
Exports Declared for the United States, December, 1898.
Financial and Industrial Conditions of the Philippine Islands.
Report National Academy of Sciences, 1898.
Memoirs National Academy of Sciences, Volume VIII.
Proceedings National Fisheries Congress, 1898.
Monthly Summary Commerce and Finance, January, 1899.
Monthly Summary Commerce and Finance, February, 1899.
Colonial Systems of the World.
Water-supply and Irrigation Papers 19 and 20.
Consular Reports, Volume LIX, No. 222.

FROM NEW YORK RAILROAD COMMISSIONERS.

Report for 1898, Volumes I and II.

FROM THE WAR DEPARTMENT, WASHINGTON, D. C.

Reports for 1898. Parts 1, 2, 3, 4, 5, and 6.

FROM THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Transactions, Volume XIX, 1898.

FROM THE BUREAU OF GEOLOGY AND MINES, STATE OF MISSOURI.

Biennial Report, 1898.

FROM JOHN BIRKINBINE.

Third Annual Report of the Pennsylvania Department of Agriculture, Part II, 1897.
Production of Iron Ores in 1897.

FROM THE BOARD OF PARK COMMISSIONERS, WILMINGTON, DEL.

Annual Reports for 1895, 1896, and 1897.

FROM BUREAU OF STEAM ENGINEERING, WASHINGTON, D. C.

Annual Report, 1898.

FROM THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Proceedings, Volume X, 1894–1895.

FROM L'ASSOCIATION TECHNIQUE MARITIME.

Bulletin No. 9, Session of 1898.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XVI. JULY, 1899. No. 4.

MODERN MINE HAULAGE PRACTICE.

HARRY K. MYERS.

Read May 6, 1899.

To the engineer of the present day, in whose hands is the success or failure of the various mining operations, there are many forms of daily expense which he is desirous of curtailing; yet, on account of existing conditions, it is a serious problem as to the method most suitable for his special condition.

One of the vital points in the production of any mineral is the transportation of the same from the face of the workings to the point of preparation, and it is almost impossible to conceive the vast amount of money expended in the various mines simply for underground haulage and maintenance of track. Previous to the past decad the question of economy was not so large a factor in the financial operation of mines, but at the present time competition in all lines is so great that the ruling prices are those at which the most advantageous mines can market their product with a fair margin of profit. In mines where natural conditions are not so favorable, it is a matter of vital importance to devise or adopt methods whereby the product can be marketed at the going prices with a substantial profit. This is more especially the case in the mining of bituminous coal, with which the ruling profit is very small and the cost of mine transportation

quite a large percentage of the price realized. Under a few special conditions it is possible to have animal power more economic than mechanic, but with the recent improvements in the latter, such favorable conditions have become exceedingly few.

In this paper it is not the intention to go into special details of the construction of the different machines used in mine haulage, but rather to point out the most modern methods as applied in general to the coal-mines of this country. Particular attention is given to coal-mines for the reason that this tonnage is the maximum of any mineral product from underneath the surface, and on account of the low specific gravity it necessarily follows that the area worked over is a maximum, and, consequently, the power necessary for its transportation is vastly greater than for any other.

To persons unaccustomed to underground workings and the rapidity with which the various gangways are advanced it is almost impossible to conceive the vastness of this subject; but when one considers that in one mine alone, with which the writer is familiar, there now exist 130 miles of track laid with iron and steel rails, and in the operation of this mine up to the present time there has existed 500 miles of such track on headings and air-courses and three times as much in rooms, making a total of 2000 miles of road construction which has been in this mine, of which about one-fourth now remains; if one simply makes an estimate of the track laid during the past year, based on a six-foot seam of coal, it is found that in the production of 200,000,000 tons it required 2000 miles of track on headings and 5000 miles in rooms. It may be said that all of this track was at such grades that it could be operated by some sort of traction, and, with such an amount of extensions each year with a total of 30,000 miles in operation, there is no reason why this class of work should not receive the full attention of the engineer and great economies result therefrom. Much has been written about preliminary, location, construction, maintenance of way, and transportation on steam surface roads, but little has been said of the underground systems.

At the present time there are fully 400,000,000 tons of different minerals produced annually over a total of 50,000 miles of mine track, with an average haul of one mile per ton at a cost of fifteen cents. In the transportation of this material it requires 100,000 mules, whose average life is four years each. To drive and maintain

FIG. 1.—GENERAL MINING TYPE OF STEAM LOCOMOTIVE.
As illustrated, it has 9″ x 14″ cylinders, working pressure 140 lbs., 28″ drivers, 48″ wheel-base, 61″ high, and 44″ gage, with a tank capacity of 250 gallons. Weight, 22,000 lbs.

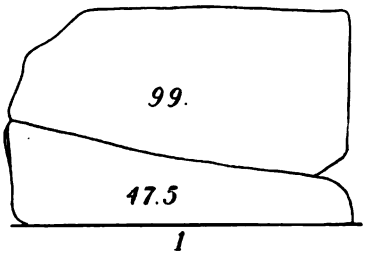
FIG. 2.—SPECIAL MINING TYPE OF STEAM LOCOMOTIVE.
As illustrated, it has 11″ x 16″ cylinders, working pressure 160 lbs., 30″ drivers, 84″ wheel-base, 66″ high, and 36″ gage, with a tank capacity of 400 gallons. Weight, 60,000 lbs.

each mule will cost $600 annually, or a total of $60,000,000 annually for mine transportation. With such an amount involved it would appear to be a matter of a short time when animal power would be a thing of the past and mechanic haulage universally adopted.

Of the various forms of haulage,—viz., rope, steam-locomotive, compressed air, and electric,—the first two have been used for a number of years. The wire-rope haul has been rather efficient, especially in straight headings and where the grades are heavy and against loads, but in the various attempts to use them in crooked gangways the cost of renewals has been very great. The mining type of steam locomotive has been used considerably, but with the perfecting of mining laws and the generally poor results obtained, they are fast going out of use. The depression of business during the past year caused mining companies to examine modern methods, that they might secure a saving in this item of cost.

About twenty years ago the question of compressed-air haulage in mines came up for consideration, but with the low pressures then advocated the range of the locomotive was such that very few plants were installed; yet in that form it was a great improvement over the original tandem compound—viz., a string team of mules. The only disadvantage in compressed-air haulage is the size of the storage tanks. As built at the present day for ordinarily heavy work, they have the following dimensions: height, 5′ to 5′6″; width, 6′ to 7′; length, 16′ to 22′. During the past ten years much discussion has arisen as to the merits of the forms of compound locomotives, but not until about two years ago was any attempt made to apply this principle to pneumatic locomotives, when the Baldwin Locomotive Works agreed to build for the Philadelphia and Reading Coal and Iron Company a Vauclain compressed-air locomotive, with the following dimensions:

Diameter of high-pressure cylinder,	5 inches
" " low- " "	8 "
Length of stroke,	12 "
Diameter of drivers,	24 "
Wheel-base,	54 "
Weight,	22,000 lbs.
Capacity of storage tanks,	160 cu. ft.
Line pressure,	800 lbs.
Tank "	600 "
Working "	200 "



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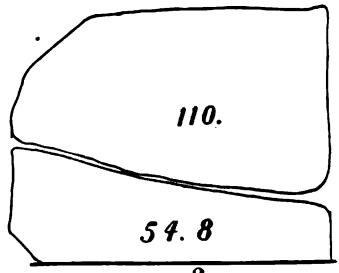

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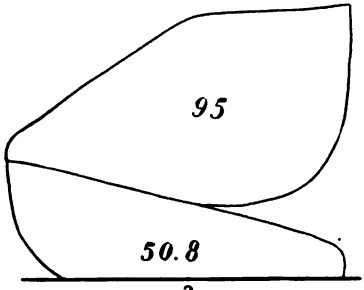

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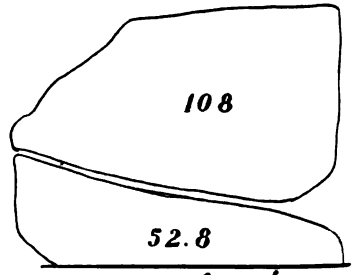

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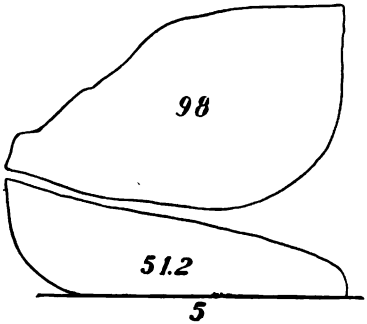

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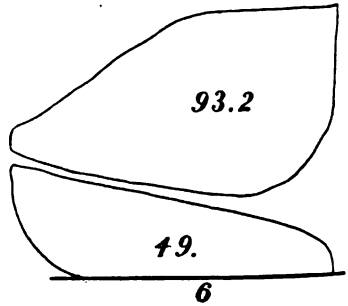


6

INDICATOR CARDS TAKEN FROM P. & R. C. & I. CO.'S NO. 44 VAUCLAIN COMPOUND COMPRESSED-AIR LOCOMOTIVE.

No.	Trip.	Trip Card, No.	Speed (Miles Per Hour).	Grade (Feet Per Mile).	Tractive Power Developed.	H. P. Developed.	Date.
1	4	1	5.3	49.1	2757	38.98	10-19-'97
2	7	1	6.7	49.1	3016	53.89	10-19-'97
3	10	1	8.0	49.1	2813	60.01	10-20-'97
4	7	3	8.0	70.2	3039	64.83	10-20-'97
5	12	2	7.3	70.2	2863	55.79	10-20-'97
6	12	3	7.2.	70.2	2733	54.27	10-20-'97

It was the intention to have this locomotive do the work of fourteen mules, and after a series of delays, the plant was completed and the locomotive was thoroughly tested, much to the satisfaction of both builder and purchaser. After a most thorough trial of eighteen months two other plants were ordered, and at the present time another large coal company is having two similar plants installed.

The economy of the compound over the simple expansion of this type is, first, that the full expansive effect of the air is realized; second, on account of the large combined cylinder surface, new energy is

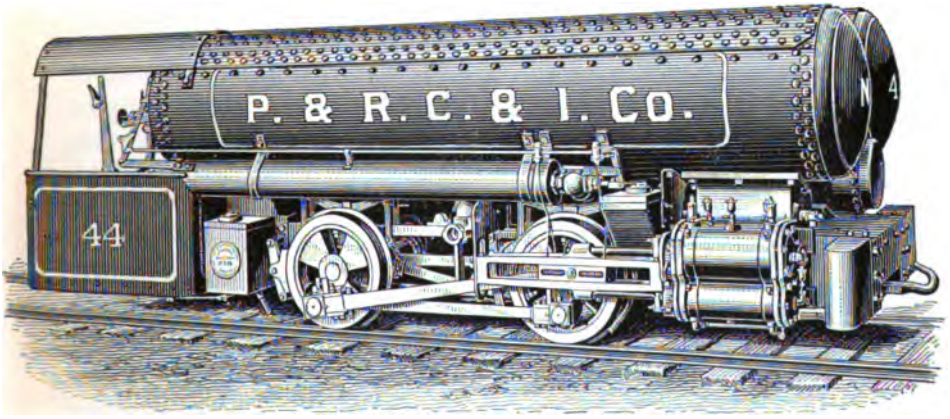


FIG. 3.—VAUCLAIN COMPOUND COMPRESSED-AIR MINING LOCOMOTIVE.

As illustrated, it has 8″ x 12″ cylinders, working pressure, 200 lbs., 24″ drivers, 54″ wheelbase, 61″ high, 16 feet long, and 38″ guge. Storage tank capacity, 160 cubic feet at 600 lbs. pressure. Weight, 22,000 lbs.

imparted to the air from the surrounding atmosphere, and, third, in the practical use of the locomotive.

In making the calculations for air consumption the various cut-offs are considered, while in the use of the locomotive the engineer invariably cuts off later in the stroke than necessary and hence exhausts at high pressure with simple cylinders; but with compound this exhaust is caught in the low-pressure cylinder and utilized. The best practical example of this saving, which is fully fifty per cent., is shown in the use of compressors of same size and make. Where the simple cylinders are used, it is impossible to keep a supply of air, whereas with the compound the compressor is running half-speed most of the time

and the pipe at maximum pressure. On account of the high pressure carried, many people are fearful of the results from explosions and go so far as to say that the factor of safety with such pressures should be greater than with low ones, but this is not the correct idea. These pressures are a maximum which it is difficult to maintain and almost impossible to exceed, hence the possibility for explosion is scarcely to be considered; while in low pressures it is easy to excel and hence increase the possibility of explosion. It is, therefore, considered good practice to use a factor of safety of three in designing the storage tanks. In the compression of air it is impossible to get the ideal; hence in compressing 100 cubic feet of free air we get practically 3 cubic feet at 750 pounds, instead of 2—the theoretic amount. If this air is expanded adiabatically, we will have 75 feet free air, or a loss of 25 per cent. It is customary to base calculations on adiabatic compression and expansion, but in the use of high pressures the errors are such that we must work with closer values if we desire reliable results.

In order to show the working of a Vauclain compound air locomotive we will refer to the records taken at the Alaska Colliery of the Philadelphia and Reading Coal and Iron Company: On October 20, 1897, the average of 12 trips was 26 empty cars, weighing 75,000 pounds, hauled up an average grade of 1.4 per cent. 2400 feet long with an average indicated horse-power of 49.4 and an air consumption of 114 cubic feet at 200 pounds' pressure. In practice this would require 9 cubic feet at 750 pounds, or 300 cubic feet free air, and to compress same would require approximately 95 horse-power, thus showing an efficiency of over 50 per cent. for the entire system. Had the air been compressed to 200 pounds, it would have only required 57 horse-power to do the compressing and the efficiency would have been 87 per cent.

In the use of compressed air in Paris it has been determined that it required 11 feet of free air heated and 15 feet cold to produce 1 horse-power. In the work cited above it required about 6 feet free air per indicated horse-power, and to transport 1-ton cars and lading 1 mile on level track with a car resistance of 1 per cent., 23 cubic feet free air. The air used at this plant is filtered through water in order to remove all dust, and comes to the three-stage Norwalk compressor thoroughly saturated with moisture; yet this moisture does not assert

itself until the working pressure is reduced to 120 pounds, when there is trouble in freezing.

For gassy mines this is the only form of haulage, and since it is necessary to have sufficient storage capacity to charge the locomotive almost instantaneously, it is customary to extend the pipe line sufficiently far into the mine so that it may act as a reservoir and at the same time afford charging stations at convenient points or for future demands.

About the time of the introduction of electricity into street-car service it became a question for discussion among the mining people as to its practicability for their use. In the early days the failures were numerous, due principally to the inability to fully understand the various freaks of motors, and kindred troubles. The system in general was looked on with suspicion, and considered entirely theoretic, and with the rough usage of mine machinery considered entirely of too dainty a nature for practical use. The dangers arising from its use were also detrimental to its installation, but this has all passed away to such an extent that bare wires are now used for feed-wires. On account of the methods for supporting these wires, it often happens that they fall down and cause serious accidents to mules. In the use of 250-volt current it is found that simple contact does not kill the mule, but if he falls on it he is certainly killed.

Of the many electric haulages installed during the past five years, very few of them have been of 500 volts, due principally to the fear of the high tension; yet the number of accidents from this voltage is no greater proportionately than for the low, and when it is considered that in the low the amount of feed-wire is greatly increased, the chance for fallen wires and danger from contact are also increased.

The numerous accidents to mules coming in contact with these wires raised a demand for some sort of a system whereby the animal will become an unnecessary evil in the operation of a mine. To construct a bonded track and stretch a trolley wire to the face of all workings would be too expensive for general mine practice, and, in consequence, it is the custom in some mines to use a small mine-wagon and have the miner push it to and fro from face to parting, from which place it is taken with the locomotive. In order to eliminate the mule from the mine and haul from the face of all workings, a combined storage and trolley locomotive has been devised, whereby the heavy work on

headings is done from trolley, and while so running the attached battery, which is carried in circuit, absorbs sufficient current to do the necessary room-work. Such a locomotive, the only one of its class, was built by the Baldwin-Westinghouse combination for the Southwest Virginia Improvement Company, having the following dimensions:

Gage,	36 inches
Width over all,	42 "
Height, including battery-box,	44 "
Length,	124 "
Weight, including battery,	9000 lbs.
Electric equipment,	2–10 h.-p. motors.
Rheostatic controller.	

This locomotive was designed to haul on the level one loaded car weighing 9000 pounds on storage, and was accordingly equipped with 90 5-D. cells, and having mounted therewith a special battery circuit-breaker, etc.

After the locomotive was built, the mine manager changed his plans and concluded to try it in a part of the mine where the battery would be required to handle loaded cars up a 4 per cent. grade and empties up 8 per cent. In addition, the trolley line was an extension of the feed line for some ten or twelve mining machines, in consequence of which the voltage varied from 110 to 200 and the battery would either feed back into the line or throw the circuit-breaker. In order to prevent the latter, it was so adjusted that it would not fly out, and the battery was virtually short-circuited a large number of times each day without any bad effect. With this condition of affairs it was impossible to hold sufficient current in the battery to do the desired amount of room-work, and it became necessary to stop a total of about thirty minutes each day for renewals. It must be remembered that this work was under the supervision of a mine foreman unacquainted with storage batteries. Having gone to such extremes in the use of this locomotive, it was suggested that a new and independent feed line would be a great improvement; it was installed, with marvelous results. The voltage became constant, and the battery often discharged for a short time at three times its rated capacity; yet the work has been ideal, and after almost three months' service there is no appreciable wear on the battery. It produces a tractive effort up to the

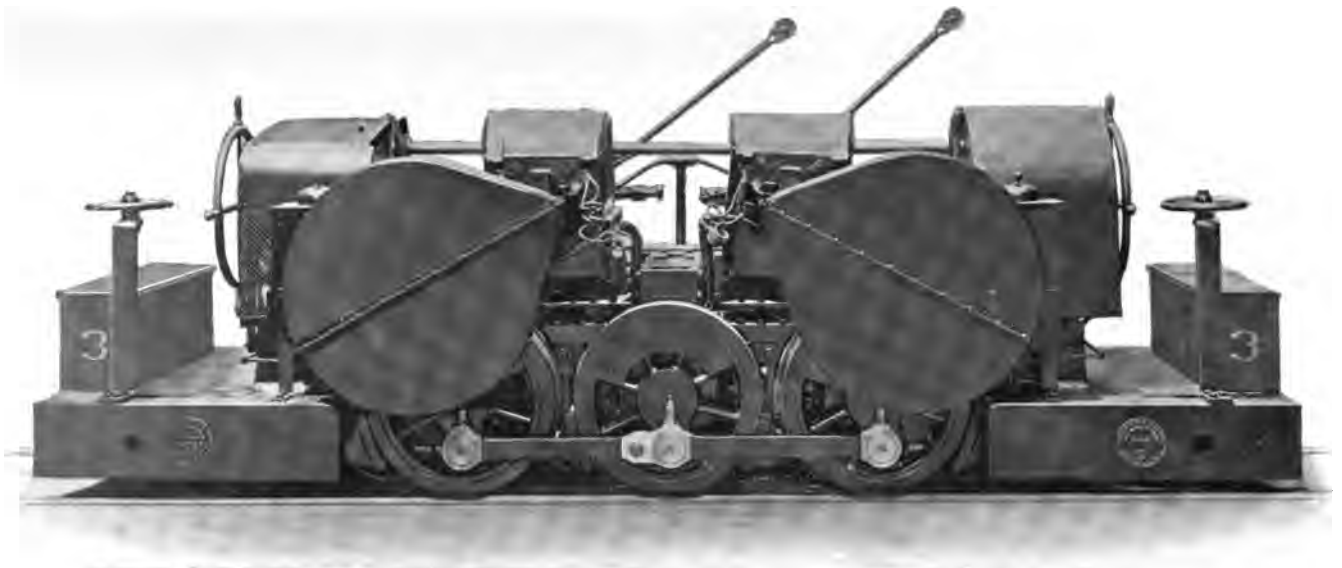


FIG. 4.—DOUBLE REDUCTION MINING TYPE ELECTRIC LOCOMOTIVE.
As illustrated, it is equipped with two 75 H. P. motors geared for a speed of 8 miles per hour. Drivers 39″, height 60″, width 74″, length 18″, voltage 500, and weight 44,000 lbs.

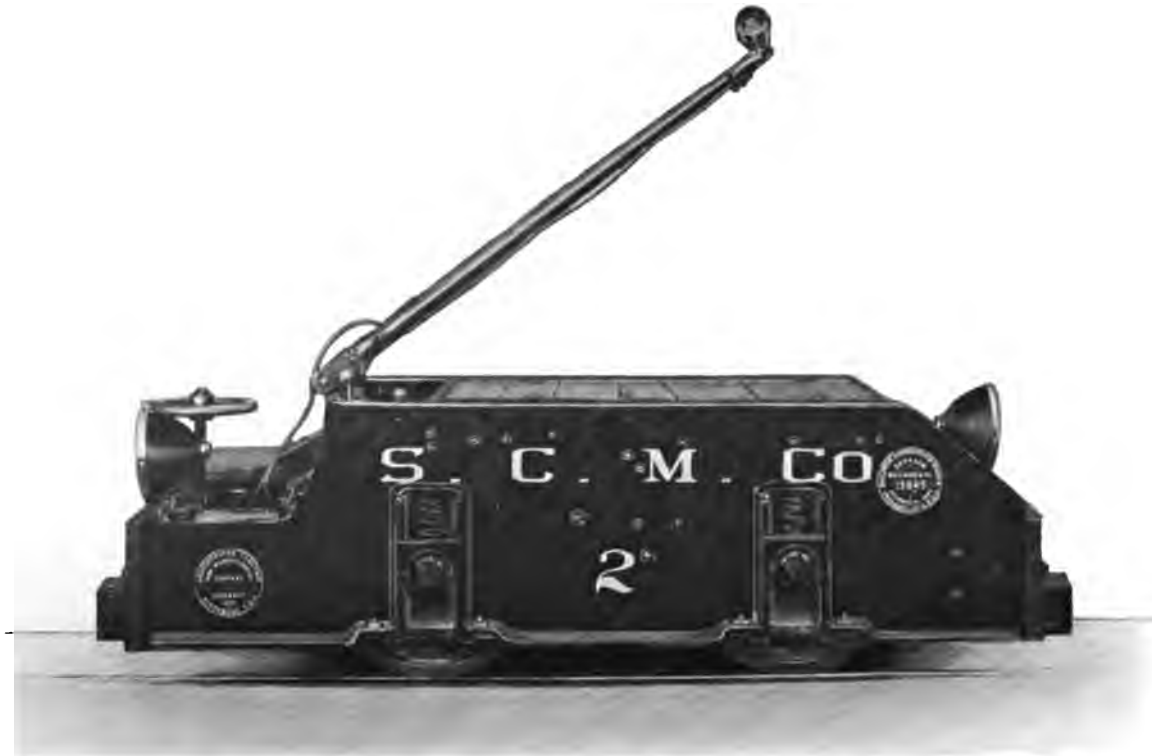


Fig. 5.—Single Reduction Mining Type Electric Locomotive.
As illustrated, it is equipped with two 10 H.P. motors wound for a speed of 8 miles per hour. Drivers 28", height 33", width 48", length 10'6", gage 30", weight 9500 lbs.

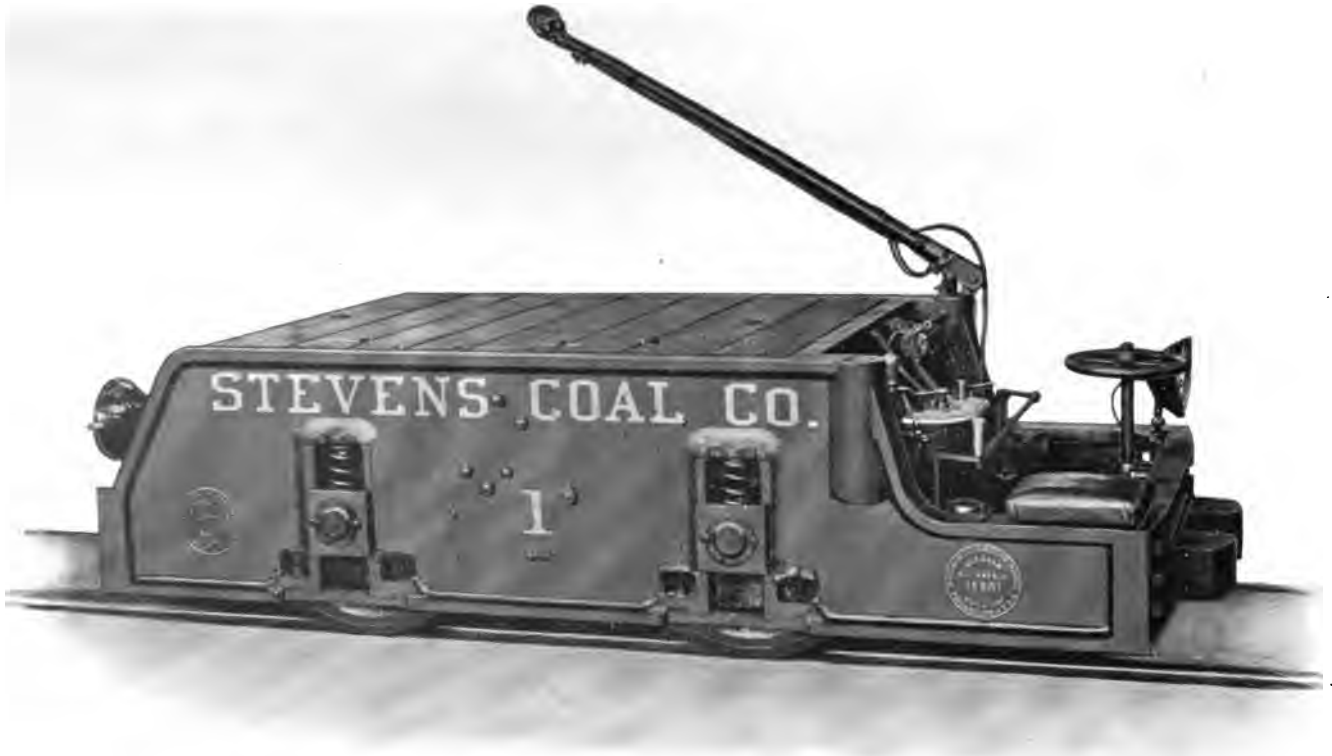


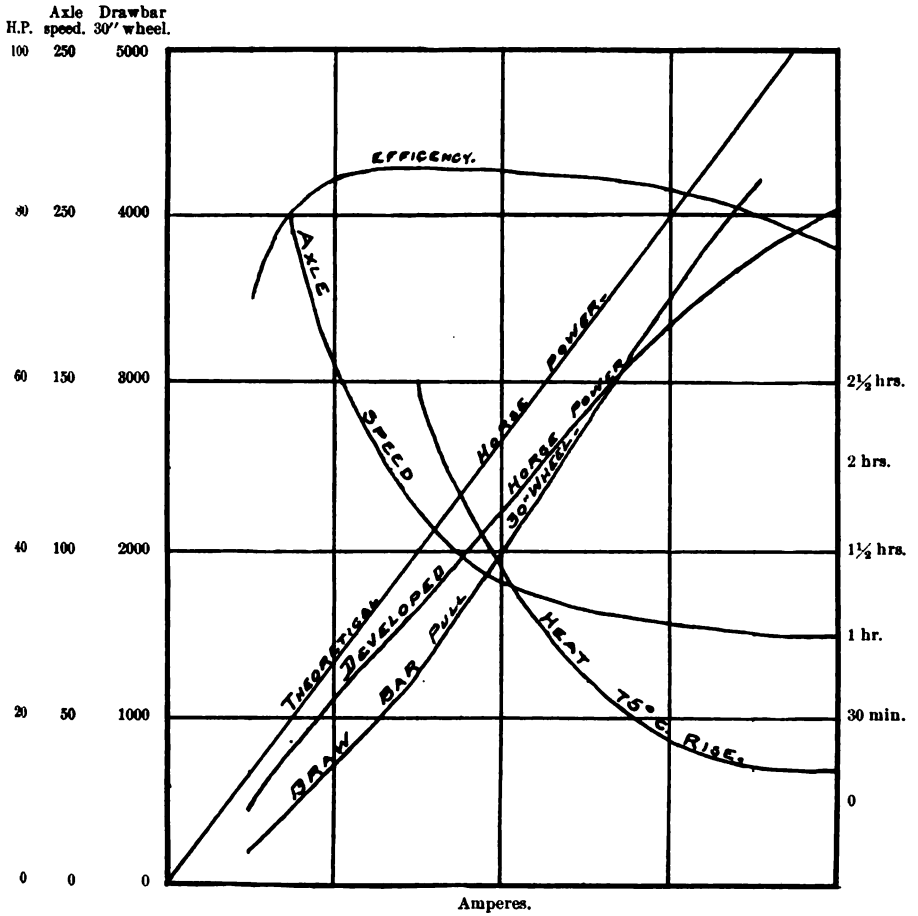
FIG. 6.—SINGLE REDUCTION MINING TYPE ELECTRIC LOCOMOTIVE.
As illustrated, it is equipped with two 25 H.P. motors wound for a speed of 8 miles per hour. Drivers 30″, height 34″, width 60″, length 11′6″, gage 42″, weight 13,000 lbs.

point of adhesion of the locomotive when working on storage, and the regular work is to take seventeen empties weighing 60,000 pounds, including locomotive, from side-track up a short 1 per cent. grade, then down a 4 per cent. to a level, from which place it starts to distribute in rooms having a maximum of 8 per cent. in favor of loads. After

FIG. 7.—SINGLE REDUCTION COMBINED STORAGE AND TROLLEY TYPE.

distribution, it proceeds to collect the loads in trips of two cars each, on account of the 4 per cent. grade against loads on heading, and deliver them to the side-track while working on trolley. In this manner this one locomotive is capable of delivering to this side-track, over an average round-trip haul of 4000 feet, 200 loaded wagons

daily direct from face of workings, which is the work, under existing conditions, of 12 mules and 8 drivers. It is the intention to place a night force, and if sufficiently large, the saving will be the care of 24 mules and time of 12 men, or an amount equal to $8000 annually.



50 H.P. Mining Motor, 500 Volts.

This same company has placed an order for six more of the same class of locomotives, and are considering the matter of constructing heavier ones of the same kind to take the place of steam locomotives

now in use, but which are very injurious to both the ventilation of the mine and the timber-work.

In general, it costs from 6 to 10 cents per ton to deliver coal from face of workings to shaft, slope, or tipple, where the haul is 1 mile and the tracks approximately level; yet I have in mind 3 mines which at present haul from parting with the trolley system, the miner delivering from face of room, making an average round trip of 9000 feet at a total cost of 1 cent per ton. These mines have never had a mule in them, and it would be almost an impossibility to introduce them, for the reason that the seam is of such thickness that the clearance between tie and roof is only about 4 feet.

Since the advent of the electric mining locomotive there has been a change in the mine-wagons universally used. Formerly it was customary to find as much as 60 pounds per ton car resistance on the level, while at present it is as low as 15 pounds.

In dimensioning mining locomotives it is customary to make the weight from 6 to 8 times the necessary tractive effort dependent entirely on the nature of the work. If the work is constant and a maximum, then the weight would be only 6 times the torque of the motors, while if the work is intermittent with a short time maximum tractive effort, then the factor would be 8. For maximum continuous work it is necessary to have a grade such that the efforts to haul the same number of empty wagons as loaded are equal. With the car resistance considered 1 per cent. and the loaded cars weighing three times as much as the empties, this is found to be one-half of one per cent. The most critical point in the designing of mining locomotives is to make the limiting dimensions a minimum. The demands for various dimensions are wonderful. The headings in mines are never of more generous proportions than really necessary, and all clearances a minimum. The minimum dimensions for mining locomotives are as small as 2 feet for wheel-base, 8 feet for length over all, and 3 width. Scarcely two orders carry the same dimensions, and it is impossible to have any kind of a standard. In consequence of this it is necessary to have a great variety of motors suitable for gages as narrow as 18 inches and for wheels as small as 20 inches in diameter. With such a variety it becomes possible to construct a locomotive weighing 40,000 pounds on 3-foot gage, having the width over all 62 inches, height 35 inches, and length 12 feet. In such construction

it is necessary to have the most modern form of motors and the most rigid mechanic construction.

The motors now used are of the best possible construction and efficiency. They are of the slow-speed street-car type, 6 to 8 miles per hour, winding, and range in size from 4 to 50 horse-power. It is customary to use the rheostatic type of controller for mining locomotives on account of its small dimensions and apparent efficiency for this class of work, but it is doubtless but a short time until a very compact form of series-parallel type will be devised. On account of the use of this rheostatic controller it becomes necessary to provide for large diverter capacity, and since the locomotive is designed for the maximum tractive effort, it is hardly ever possible to run without resistance, and hence a large amount of current must be dispersed with the consequent heating.

The demands for mining locomotives come from all quarters of the globe, thus showing that engineers in every section are awake to the fact that modern mechanic appliances are an absolute necessity in the art of mining.

In order that a comparison may be made between a mule and a locomotive, I have deduced from practical observation that the former as well as the latter can produce a tractive effort of one-fifth its weight for a maximum and one-seventh for regular work, thus showing that the mule is a very efficient machine so far as effort is concerned, but very deficient as to speed.

In conclusion I would say that it is my belief that in the very near future compressed air and electric locomotives will as thoroughly displace the mule in mines as they have the horse in street-car service, and although I have no desire to organize a crusade against this noble servitor of man, yet the demands of the investor for increased capacity with decreased cost are such that there is no other alternative than to accept the inevitable and adopt modern methods and install the most modern machinery.

DISCUSSION.

THE PRESIDENT.—The experience gained in connection with these locomotives using compressed air is specially interesting in the application of compounding. It was held that compounding would prove a failure because of the resulting back pressure, which would annul any benefit from expanding.

MR. MYERS.—It was found that while there is loss in steam, there is gain in

compressed air by reheating. The efficiency of compound compressed-air locomotives is greater than compound steam locomotives. Persons who have examined them have found them ideal. The results are very satisfactory.

JOSEPH T. RICHARDS.—In comparison, are more or fewer mines operated by compressed-air engines than those operated by electricity?

MR. MYERS.—There are not over 50 compressed-air locomotives in use in the United States at the present time. There are possibly 250 electric locomotives. A compressed-air plant is more expensive to start with.

MR. RICHARDS.—Suppose the air is carried at a greater pressure,—say, two or three thousand pounds,—would not this permit reduction of the size of the locomotive?

MR. MYERS.—Very much. That has been tried, but the economy is not very great with high pressure. Seventy-five per cent. of efficiency is obtained by the electric motor, while fifty per cent. is the maximum with the "triple expansion" compressor and compound locomotives.

HARRISON SOUDER.—What is the comparative cost of steam locomotives and air-engines, and what is the price of the compressed-air locomotives?

MR. MYERS.—Steam locomotives are less expensive, for although they may be bought at the same price as compressed-air engines, for the latter there are needed boilers and compressors. The cost of the compressed-air locomotive depends on the size of the cylinders; for the 5 x 8 size, about $2600. We are now building for the H. C. Frick Co. some which weigh about 30,000 pounds, costing about $3000. They will be the largest air locomotives ever built.

CARL HERING.—Is the air dried before it is compressed, so as to prevent freezing? and if it were thus dried, could there be any freezing in the cylinder during expansion?

MR. MYERS.—It has been the practice in coal-mines to filter the air through water to remove dust, and it goes through the compressor full of moisture, yet it does not freeze until it gets down to working pressure of 120 pounds or lower. I believe it is claimed that in working with high pressure the moisture is forced out of the air. The compressors are provided with drip-cocks, but these are scarcely ever used unless the mines have been lying idle for a week or so, when moisture will gather in the pipes.

THE PRESIDENT.—In regard to corrugating or ribbing the external surfaces of the cylinders for the purpose of increasing the dissipation of heat, my recollection is that the conclusions reached some years ago were that the absorption or dissipation of heat would not be increased by these means. Certain styles of steam-heaters were manufactured some twenty-five or thirty years ago which had projections in the forms of tits and ribs cast on the sides for the purpose of increasing their efficiency. The use of such heaters was discontinued, as no gain resulted from the projections. From the remarks of Mr. Myers it appears that something was gained by ribbing the outsides of the cylinders of these locomotives.

E. M. NICHOLS.—Regarding the point to which the President refers, that of radiators with extended surface, it has been demonstrated that flue radiators

which are provided with thin ribs projecting from the plain surface of the body of the radiator are much less efficient than where the undulations on the outside have a corresponding undulation on the inside and a uniform thickness of metal. The reason of this is that in the transmission of the heat to the thin ribs it passes through a very small section compared to the surface which it supplies, consequently the temperature is much lower.

In the particular case that Mr. Myers calls to our attention the undulations are not very abrupt, and consequently the thickness of the metal does not vary so much ; but in the absence of any exact data as to the relative efficiency, comparing the absolute surface exposed to the atmosphere in the corrugated cylinder which he mentions to a cylinder with ordinary plain surface, I am inclined to think that the increase is not very great.

The efficiency of iron to transmit heat to the air depends largely upon the difference in temperature between the atmosphere on the outside and the velocity with which the air passes over it. When the air has become highly heated, of course there is less condensation or transmission to heat than is the case where it is absolutely cold.

This is well recognized among engineers in the heating business. With radiators of which the cross-section is the same, the efficiency of the shorter ones—say from 18 to 20 inches—in transmitting heat is nearly as great as one with the same cross-section which may be from 2½ to 3 feet in height.

THE UTILIZATION OF WASTE.

JOHN BIRKINBINE.

Read May 20, 1899.

THE purpose of these notes is to suggest the importance of utilizing what we consider as waste, instancing a few applications, with the expectation that others will present, in more or less detail, means which are or which may be used to transform refuse into articles of value.

Without detracting from the credit deservedly given to the person who causes "two blades of grass to grow where one had thrived before," or to another who contributes to "make the desert blossom as the rose," prominent places among the benefactors of mankind may be claimed for those who utilize what is or what has been considered as waste.

Webster defines the noun waste, in the sense of the present discussion, as "lying unused, unproductive, of no worth." Applying this definition, the man or woman who reclaims what is unused, converts to good purposes that which is unproductive, or brings value to that which is esteemed as worthless, benefits mankind, and adds to the material wealth of the world.

What is the waste or refuse of one industry may be and often is the raw material of another, but the extent to which such waste can be used is influenced by local conditions. It is comparatively easy to point out waste in nearly every process of manufacture, in our homes, and in our method of living, but to correct this is, in many instances, impracticable. We recognize how great the waste is in all departments of industries and in our households, and few realize how much is being done toward utilizing this refuse material. But with all that has been accomplished, there is a wide field to be covered before we reach the Utopian condition where a useful purpose is found for all that is now waste or considered as such. The many scavengers who extract value from the proceeds of the city dump-heaps in waste paper, rags, old leather, coal, bottles, or old metal, probably represent the most popular notion of the utilization of waste products, a utilization more important than is ordinarily appreciated, and representing

gross money value which would appear fabulous. The army engaged in this reclamation is large and its scouts appear at every dump, upon the scenes of every fire before the embers are cooled, or assail our homes to collect whatever of apparent value may be obtainable.

The late Colonel Waring asserted in a magazine article that in the present state of knowledge the refuse from a city of 50,000 inhabitants possesses sufficient commercial value for the municipality to derive revenue from the sale of the privilege of collecting it. The facts that old rags and paper enter into the production of other paper, that scrap-iron and other metals are transformed by the cupola or furnace into new forms, that leather-scraps are useful in chemical manufacture, apparently cover the extent of popular knowledge, unless the legend is accepted that old paper, tin cans, and bottles are the most nutritious food for goats. An inventor of a pulverizing apparatus, in inviting attention to his invention, asserted that his machines were employed to reduce old bottles, broken crockery, etc., into impalpable powder as a constituent of a well-advertised scouring soap. The city waste is of enormous proportions, and the refuse from homes and manufactories is great. In addition to the manufactures or special industries which depend upon the waste of others for raw material, there are those which are profitable only because their waste is put to some useful purpose. In some instances the original product is now the by-product, and what was formerly refuse, represents the greater proportion of value.

The possibilities of utilizing waste in a single direction were suggested by a visit to a large button-works in Connecticut, where I was informed that ninety tons of buttons had been made in one month. It is impossible to suggest the number of buttons represented by ninety tons, or to imagine the multitude of stitches required to fasten them to clothing, or even to guess at the number of "swears" which were encouraged by the failure of individual buttons to maintain their responsibility. The material used to produce these buttons was the remnants of the sheets of tinplate from which the bottoms and caps of cans for blacking and other boxes had been cut. After the button blanks had been punched from this tinplate, the small triangles of metal connected by iron threads were compressed in a form under a drop-hammer and subsequently shipped away to be made into sash-weights.

Some of the prominent utilizations of waste products which are well known to-day are in connection with the fuel-supply. In the production of charcoal from wood there are large volumes of acetic vapors which, when condensed, are of considerable value. By charring the wood in ovens or retorts and conveying the vapors to condensers and stills, the products are charcoal, pyroligneous acid, tar, and uncondensable gases of considerable thermic value. These gases are used as fuel, the tar is merchantable, and from the pyroligneous acid methyl alcohol, acetic acid, and various commercial acetates are produced. The influence of locality is quite marked in this utilization, for at some iron-works many thousand cords of wood are annually converted into charcoal, the pyroligneous acid as a by-product being made into acetates and wood-alcohol. At other works the wood is charred to secure the pyroligneous acid, the charcoal being a by-product, but most of the wood cut for charcoal is charred and no effort made to collect the acetic vapors.

The same principle holds in regard to the manufacture of coke. As a rule, the products of distillation from the coal while being coked pass off into the air as dense smoke and are wasted, but at a number of localities in this country and abroad the volatile matters are condensed and commercial ammoniates, tar, and gases of calorific value are utilized. It is claimed that, in addition to the commercial by-products from coking, ten tons of average bituminous coal, incondensable gases, equivalent in calorific value to one ton of coal, result.

A liberal portion of the coal-supply of Philadelphia to-day is made up of sizes which were considered unmerchantable, and which were consigned to the waste-heaps within a few years. Now this coal finds a ready market and piles of refuse are being reworked to secure the smaller sizes of coal available, and in some cases the refuse from the washeries (which is mainly disintegrated shale) is utilized to fill the portions of the mines which are worked out. Coal-waste was considered of sufficient importance to have a State Commission appointed to investigate it a decad ago. Special furnaces, grates, etc., to utilize this small coal are designed, and there is wide-spread interest in smoke abatement. The disintegration and washing of inferior coal to produce coke, the employment of the gas-producer, are incidental to the utilization of what otherwise would be wasted.

A prominent American utilization is the cotton-seed. Throughout

the cotton belt of this country numerous mills are operated which convert the cotton-seed, formerly left in piles to rot or to be burned when sufficiently dry, into oil and food for cattle. Cotton-seed mills are features of many Southern towns, and are sought for as industrial developers by municipal promoters. The cornstalk, whose only functions appeared to be to contribute to the manure-pile or to serve as food or bedding for cattle, seems destined to find a considerable utilization in producing cellulose. The pith of the cornstalk is treated to produce this remarkable product, the balance being transformed into compressed cattle-food.

In the iron industry there are numerous applications in utilizing waste or refuse, including the production of cement, mineral wool, paving blocks, or monolithic paving, from blast-furnace cinder; the remelting or converting of unmerchantable masses of metal, ladle-sculls, crop-ends, shearings, punchings, filings, etc.; the rerolling of rails; the utilization of blast-furnace gas to heat air, produce steam, etc.; the restoring of the exterior heat of an ingot by means of a soaking pit, and the sinking of scrap in forges and furnaces; the almost universal generation of steam by waste heat, etc., in mills, etc.

One need not be classed as old to recall the scum which covered every stream draining a gas-works. The resulting tar, the ammoniacal liquor, the coke, are all now put to use, and from the former some marvelous products result. We would hardly expect the sweetest substance known, or the nearest imitation of the flavor of the vanilla-bean to be coal-tar products, nor do the marvelous anilin colors suggest coal as their ancestor. The petroleum industry abounds in interesting surprises of products made from what were formerly waste, which some of our members can describe better than the writer. Many carbons used in electric engineering are formed of what was a waste product from petroleum distillation, or from gas retorts.

The various systematic methods of exploiting mines and applying timber supports to the workings permit of obtaining a larger proportion of mineral from a given area, and the application of chemistry to metallurgic process aids in extracting from what was formerly waste rock much that is of value. The chlorination, the cyanid and other processes, recover precious metals from what until late years was considered unproductive rock.

The condensation of fumes resulting from roasting ores, the treat-

ment of acids or liquors which have performed their purpose in manufacturing processes, are instances of the utilization of waste. The mining city of Butte, Montana, is now demanding some process which will utilize the sulphurous fumes from the smelters, which make life in that city undesirable—a waste product which some day will represent great value, but which now demands large expenditures to get rid of.

Water strongly impregnated with copper is pumped from the copper mines, passed over old scrap-iron, to which it adheres, and in this way large quantities of fine copper are recovered. The blue billy, which is a by-product in the treatment of iron pyrites for the manufacture of sulphuric acid, is an important portion of the charge of many blast-furnaces, and the silicate of iron left after abstracting copper from cupriferous pyrites has a similar use.

The lumber industry supplies numerous instances of refuse utilization, and in many localities the proportion of slabs, strips, etc., fed to the "hells" is much below what prevailed a few years ago. The cores cut from pump-logs are made into pillars or round posts, the slabs are cut into box-boards or lath, shingles, etc., and sawdust compressed with a cementing medium is also formed into imitations of carving. A number of minor wood-working industries rely upon the waste from sawmills, and in the mills the effort to reduce the loss in sawdust has developed the band saw with its narrow "kerf." At some Swedish iron and steel works sawdust and sawmill refuse are gasified, the gas, after being freed from moisture, being used as fuel.

Instances of utilization might be multiplied, but those mentioned may suggest to some present various means employed in special industries to convert to a useful purpose what was refuse. The admission that in our modern steam-engine only a modicum of the calorific energy stored in the fuel is used, shows that a wide field is still before us in reducing waste. The water powers which are being utilized demonstrate how great is the power which has been permitted to go to waste, and which in many cases may be conserved. Perhaps enough has been said to suggest how numerous are the utilizations of refuse, and how many are the opportunities for future advances. That there is a use for everything we all admit; that practical use can be made of everything will depend largely upon local conditions. But it is evident that the industry or municipality or home which is able to obtain

the greatest value from what under normal conditions is wasted most nearly approaches this ideal.

DISCUSSION.

MAX LIVINGSTON.—I made some notes while listening to Mr. Birkinbine. The first thing occurring to me was tin scrap, one of our waste products. Years ago the river-bank was lined with tin scrap. To-day we do not find any. In fact, we have more demand for scrap tin than we can furnish. Coming to the petroleum industry proper, in 1865, or the early sixties, it was common to run our residuum, also the naphtha, into the river. At that time I was located at Pittsburg, and we found the Allegheny River a very convenient receptacle. The lumbermen would bring their rafts down the river, and by the time they reached Pittsburg they would be beautifully painted. To-day this tar is a most valuable product. It furnishes us the paraffin oil for lubricating purposes, the valuable wax which has revolutionized many industries, and the residuum of the tar gives us coke for carbon points, and, under certain conditions, asphaltum. This asphaltum is used for roofing, also for paint. Benzin or naphtha it is not necessary for me to talk about. We all know by the daily papers the accidents placed to its credit, which, however, are due invariably to carelessness. As stated, this benzin was formerly run into the river, and on one occasion set the river on fire. In regard to the disposal of the tar, an incident comes to my mind. It was in the early days of the direct-acting pumps. Such pumps were expensive and rather scarce, and one pump had to do service for different purposes. We had in our refinery a shower bath; it simply depended on the turning of the cock as to what kind of a bath one would get. I know one day I got a beautiful tar-bath, and could not get the tar out of my hair for three or four weeks.

Looking backward twenty-five years, it seems, in the light of industrial improvements, to be delving into ancient history, though what I want to say is not exactly to the point in regard to waste. It occurs to me just now that an acquaintance of mine living in Pittsburg had to go to a hospital in New York. He brought his boy over to New York last week, and the most wonderful thing that that boy observed in New York was a street-car run by horses. He had never seen anything like this, and considered it a most wonderful improvement. I really do n't know that I can add anything more to what Mr. Birkinbine has said.

MR. BIRKINBINE.—The utilization of tin scrap is one of those questions which have been discussed and a good lot of money spent to know whether the tin was worth saving or not. Probably Mr. Livingston can tell us some of the forms they cut it into.

MR. LIVINGSTON.—Our tin scrap consists of very narrow strips, hardly wider than one-eighth of an inch. As it is ordered cut to the sizes needed, the pieces are too small for making buttons. The scrap is used in a very simple way, being melted down and molded into sash-weights. In regard to the wax, it is used for many purposes. A very large demand comes from the manufacturers of chewing-

gum, paper, and matches, and particularly from candle-makers. It is also deemed valuable for impregnating yellow pine used in house-construction.

HARRISON SOUDER.—What is the object in saturating the pine?

MR. LIVINGSTON.—I suppose it is for the purpose of giving it a glossy appearance and keeping out moisture. Referring to the use of sewage for fertilizer reminds me of a by-product in the petroleum industry that is now very important for making fertilizers—namely, sludge acid. In years gone by we were very anxious to pay parties to take our sludge acid away. To-day it is a source of revenue.

THE PRESIDENT.—For what is it used?

MR. LIVINGSTON.—For making fertilizer.

THE PRESIDENT.—Also for mineral paints?

MR. LIVINGSTON.—No. In the manipulation of the sludge acid we obtain a tar which formerly was a great nuisance to us; at present it is utilized as fuel.

JAMES CHRISTIE.—It is a common charge to make against Americans that we waste what many other people would utilize. I think there is very little doubt that this is true to some extent. It usually occurs that where nature is very bountiful, the people naturally become wasteful. Where the struggle of life is very intense, and the pressure is very great for the means of existence, materials that would elsewhere be wasted are utilized. Aside from the minor economies of life and the purely personal habits of society, we observe, in this era, attempts to utilize materials hitherto wasted which involve the employment of large capital, combined with trained intelligence, for a successful effort. No man desires to spend a dollar for the purpose of saving ninety-nine cents, and this is a frequent result from attempts at the utilization of sewage; and we know of instances where private enterprise has been supplemented by public funds for the purpose of making it profitable. The economic disposal of sewage is a vital problem of the present and of the future, for, aside from the economies that may result from its utilization, the most important question is the sanitary one; and it is not definitely known yet if any proper disposal of sewage can be accomplished without a financial outlay exceeding any result in profit.

Mr. Birkinbine has just referred, among other matters, to the losses incurred in the ordinary methods for the production of charcoal and coke, more especially of coke. The waste of fuel-gas, so plainly visible from the old bee-hive ovens, is avoidable by the modern system of coking coal in the closed retort. By-products of fuel-gas, tar, and sulphate of ammonia are recovered by the later coking process. Although this method, as yet, produces but an inconsiderable proportion of the coke output, yet its effects are observed in the reduced market value of sulphate of ammonia. Another product, hitherto entirely waste, is the slag from blast-furnaces. It is largely used now everywhere as a substitute for stone in concrete. It is an excellent material for this purpose, being much lighter than ordinary stone, and entirely fireproof. In the granulated form it becomes an excellent substitute for sand for cement-mortar, and in many parts of the country, where sharp bar-sand is neither abundant nor cheap, it can be used advantageously. Another excellent substitute for sand for the same purpose is ordinary coal-ashes, and this has been used to some extent with satisfactory results.

The vacant lots of our city suburbs are frequently disfigured by the dumpage of oyster-shells. Now, oyster-shells make an excellent top dressing for macadam roads, making less dust than ordinary stone; and we have in the northern end of the city a road with an oyster-shell top dressing subjected to heavy traffic, and giving good results.

The exhaust from steam-engines constitutes a serious nuisance in all our cities, and, incidentally, involves a waste which could be prevented. The successful application of the cooling tower to the condenser renders it possible for steam-users to run their engines condensing without paying large water bills. In the textile mills of this city it is a common practice to operate engines with several pounds' back pressure on the exhaust steam, for the purpose of utilizing the exhaust for heating purposes. With the compound condensing engine, steam of about the right pressure and temperature can be taken from the receiver, thus furnishing it at little cost for the purpose required, and, at the same time, allowing the use of condensing engines.

HARRISON SOUDER.—We have all heard of the utilization of sewage as material for fertilizing farms. I have never heard of using it as a water-power. I have often thought of this matter in connection with some of the city works—the Pennsylvania Avenue subway, for instance, where there are some large sewers carrying considerable quantities of water and sewage at high velocities. Now, of course, the amount of water and sewage varies in quantity, but my observations show that these variations are not very large in certain main sewers, and my idea was that you could put in a specially constructed water-wheel which would allow the heavy sewage matter to pass and yet not obstruct the operation of the wheel. This wheel could operate an electric motor, and, in times of high water, you could charge storage batteries, which could operate when the sewage flow was much less. I do n't know whether sewage has ever been utilized in this way, but it struck me as being feasible.

BUILDING THE NIAGARA GORGE RAILWAY.

GEORGE A. RICKER.

Read June 5, 1899.

BENJAMIN FENTON and Ensign Bennett probably first entertained the idea of constructing a railroad in the Niagara Gorge and organized a company to build a line from the "Maid of the Mist," landing in Prospect Park to the Whirlpool, to be operated by steam, the track to have a gage of thirty inches. Failing in the effort to purchase right-of-way, the Niagara Falls & Whirlpool Company instituted condemnation proceedings, but the Court of Appeals decided that it was not a railroad "organized for a public use within the meaning of the statute"; that it did not "meet the requirements of the railroad law"; it did not "connect with other lines"; "it was not a common carrier, but was merely a private line for sight-seeing purposes," and therefore could not be permitted to exercise the right of eminent domain.

According to the old notebooks, surveys were begun by Mr. J. E. Shields, the engineer in charge, on March 29, 1886, and show a daily progress of only a few hundred feet, indicating the difficulties and dangers encountered. The appearance of the slope at the water's edge, as seen from the top of the high bank, gives no adequate notion of the tangled character of the vegetation below and the insecure footing over which, for a great part of the distance, it was necessary to scramble on all fours, and the balance of the line presenting almost vertical cliffs frowning over angry waters below. From the Buttery Elevator to Suspension Bridge the survey was made by triangulation from a base line established on top of the Canadian Bank. From the bridge to Prospect Park the work was easier, the line passing over the talus beside the quieter waters of the Upper Channel. An attempt was made to cross-section the line, but it was given up as impracticable, and such estimates of quantities as were obtained must have been arrived at by rough approximation. Invitations were extended to contractors to bid on the work, but, so far as I have been able to learn, they all declined to make proposals based upon quantities. After a

NIAGARA GORGE BEFORE RAILROAD WAS BUILT.

brave struggle for existence against the united opposition of citizens, land-owners, and interested corporations, the Whirlpool Company rested and took account of its forces, to determine, if possible, upon some more feasible line of battle on which to renew the fight.

In 1889 Capt. J. M. Brinker, of Buffalo, an experienced coal-miner and railroad man, formed a company to build the railroad in the Gorge from Niagara Falls to Lewiston, and, as will be seen, his plan of extending the line was the salvation of the project. It was the practicable thing to do, for with connections at the Falls with the electric and steam roads entering that city, and at Lewiston with the New York Central and the Steamboat lines for Toronto, the character of the undertaking was changed in the sight of the law. The new road was to be a double track, standard gage railroad, to be operated by "steam, electricity, or other motive power." The stock of the Niagara Falls & Whirlpool Company was purchased, and the new company became the possessor of all rights and privileges enjoyed by the old, and bound to carry out its obligations.

The temper of the people of Niagara Falls was very unfriendly. The "Gazette" of that city of December 27, 1890, said: "The 'Gazette' has favored and will favor the coming here of all legitimate railroads, but this railroad holds a unique position, and, unless its officers act in a very different spirit from that shown by the Whirlpool Railroad, with which it proposes to merge, the 'Gazette' questions the advisability of welcoming it with open arms. As to the question of defacement of the natural scenery and the legal question involved, on which the Whirlpool Company has already been beaten in the Court of Appeals, there is plenty of time for future discussion." In the same issue appeared an article descriptive of the new project, in which the Hon. Peter A. Porter, a member of the distinguished Porter family, which, a few years ago, relinquished to the State of New York Prospect Point and Goat Island, that now make up the beautiful Niagara Park, suggested that the two great points of contest would be at the Buttery Elevator and Deveaux College, and predicted a sorry failure for the enterprise.

What the arbitrary methods of the Whirlpool Company failed to secure during its life, Captain Brinker, ably assisted by his counsel, Herbert P. Bissell, with considerable diplomatic skill acquired in a few months, and in September, 1890, the survey of the new road was

BELOW WHIRLPOOL.

begun, retracing as far as possible Mr. Shields' line from Prospect Park to the Whirlpool, and producing it northward to Lewiston, following the irregularities of the bank and keeping about twenty feet above the water. Several parcels of right-of-way were purchased without great difficulty as a result of the more persuasive methods of the new company, but when an attempt was made to secure right-of-way across the lands of the Niagara Falls Hydraulic Power & Manufacturing Company, better known as "The Schoellkopf Company," overtures were met by Mr. Schoellkopf with great coolness. He believed that building a railroad beneath the bank in front of his mills would seriously interfere with their operation, and steadily opposed all attempts to secure the coveted strip of land. After many fruitless meetings, legal proceedings were begun against the Manufacturing Company for condemnation. The case was referred to a Commission, many witnesses called, and much expert testimony was given. Mr. Wallace C. Johnson, Member of the American Society of Civil Engineers, engineer for the Schoellkopf Company, testified that the railroad would seriously hamper his company in its work, and that it would be impossible to so build it as not to practically destroy the value of the water-power of his company. He produced plans showing the great power-house about to be built at the foot of the bank, which now supplies electric energy propelling the cars of our road. After the testimony was all in a trip of inspection was made, when the Commission, accompanied by the principals in the action, with their attorneys and engineers, were conveyed by the little steamer, "Maid of the Mist," along the bank of the river as far northward as it was safe to go, obtaining an accurate view of the location. The verdict of the Commission was favorable to the railroad company, but imposed the condition that in passing the site of the intended power-house of the Schoellkopf Company, the line should be diverted outside of the proposed building. An appeal taken from this decision also resulted favorably to the railroad, and the final outcome of the litigation greatly enhanced its reputation. It was now determined beyond question that the Niagara Falls & Lewiston Railroad, unlike its predecessor, was a full-fledged railroad within the meaning of the statute.

A strong enemy of the original road remained, namely, Deveaux College, but the trustees of this institution, evidently impressed with

the strength of the new company, avoiding litigation, entered into negotiations for the sale of right-of-way desired, a price was agreed upon, and the fee of the land passed into the company. The Buttery Elevator was next obtained for $119,000, and the Van Horn and Rapids View Elevators for $90,000. As will be seen from these figures, the right-of-way was expensive. After these significant victories the owners of the balance of the land became more tractable, and by commission or purchase the entire right-of-way from Niagara Falls to Lewiston was obtained in reasonable time. As is usual in all railroad locations, the owners, protesting that their property would be ruined, adopted such methods as would secure for them the highest price for their land. It is difficult to understand to what use they could have put this debris slope, lying from two to three hundred feet beneath the walls of the gorge, and about as inaccessible as land could be.

Mr. Schoellkopf, still anxious to prevent the location in front of his mills, made the valuable suggestion of carrying the line by easy grades up the high bank, and continuing through streets to direct connection with the Niagara Falls Street Railroad. The suggestion at first seemed impracticable, on account of the great height to be overcome to cross over the New York Central tracks on the upper edge of the cliff, but careful examination determined the feasibility of an undercrossing, reducing the height to be overcome about forty feet. The final location of the crossing of the Central and the line in Second Street was not made until after much of the lower part of the road had been built and put in operation.

The peculiar location of this railroad and the unusual difficulties attendant upon its inauguration seemed to warrant the somewhat long description I have given of the business side of the enterprise. Less enthusiasm and less determination than was possessed by the officers of the new company would have resulted in discouragement before reaching the time for construction.

In order that we may better understand the actual operation of building, I will refer briefly to the geology of the Gorge, with which some of you may not be entirely familiar. For our purpose the Gorge may be best considered as made up of three distinct sections: the upper or newly made channel excavated by the constantly receding falls; the middle or original channel, which is of preglacial origin, and the

lower or postglacial channel. The characteristics of the typical cross-sections of these three channels are widely different. The preglacial section is of least width, and has nearly vertical walls extending almost to the water on the American side. The postglacial section is wider and has vertical walls to about one-third the depth of the Gorge, and steps down to the water which are covered with debris that has accumulated by regular contribution from the exposed walls above. The new section, which extends southerly from the railroad bridges, is much wider than the preglacial channel and has slopes or tali reaching nearly to the tops of the cliffs. This debris is much deeper than that resting on the steps of the lower channel, and no excavation has as yet been made of sufficient depth to disclose the steps.

The river is now flowing through the Medina sandstone, which underlies all western New York. The railroad at frequent intervals passes through sections of sandstone, and practically all the rock excavation was made in the quartzose belt of this stratum. Above the sandstone lies the Clinton limestone, over that the Niagara shale, and at the top of the cliff, the Niagara limestone. While the railroad follows the irregular line of the foot of the talus from the Whirlpool to Lewiston, the directions of the entire channel form, roughly speaking, four tangents. The new channel is about two miles long and extends, approximately, northeasterly from the present fall to the railroad bridges. The preglacial channel is about one mile in length from the bridges northwesterly to the Whirlpool. The waters leave the Whirlpool in a direction nearly at right angles to that at which they enter, and continue northeasterly to the Devil's Hole, a distance of about two miles, and from the Devil's Hole to Lewiston, about two miles more, running almost due north. The continuation of the preglacial channel, known as St. David's, lies directly to the northwest in the extension of the line of the Whirlpool Rapids, and is plainly marked, but is nearly filled with glacial drift.

About the 1st of April, 1895, an agreement was entered into with Messrs. Crage & Tench, contractors of Buffalo, to build the Gorge Railroad, in which the contractors were to secure the men, furnish all necessary tools, and their services for ten per cent. of the force account. After five tedious years of waiting the company suddenly decided to proceed with construction, and I received a telephone mes-

FALLEN ROCK-MASSES, 1899.

sage from President Brinker to the effect that "the graders would be at Lewiston to start work to-morrow morning," and asking me to be on hand to give necessary directions. Construction was begun at Lewiston on April 11th, and a few weeks later at several points along the line between Lewiston and the Buttery Elevator. Beyond a profile, which it was afterward found impracticable to follow, no plans were made as the result of the original survey.

I am now confronted with a task more difficult than that of building the railroad—how to tell you in engineering terms of the construction of this road that was built in a most unscientific manner. My orders were to put a railroad in this unpromising place, and I proceeded forthwith to obey. Before stakes were set a path was graded, following, as nearly as possible, a few feet above the proposed grade-line, and gangs of laborers were placed at frequent intervals. No reliance could be put upon any slope made outside of the natural slope. Had classification been attempted, but two kinds of material would have been named: loose and solid rock, as the talus is made up of large and small stones with not sufficient earth to fill the interstices, and with no cementing material, although the roots of dense vegetation tend to hold it in place and maintain a much stronger slope than would otherwise be possible. The deep channel of the river afforded the very best place for wasting the material excavated, and work proceeded rapidly. From 600 to 1000 men were employed, and the first five miles to Buttery Elevator roughly completed, and one track laid, and the first train entered this temporary southern terminus August 25th. On the inner side of the road-bed such a slope was formed as would stand for the time being, which, of course, meant that the heavy rains and the frost in the coming spring would bring down large quantities of material left on the steps above. Cross-overs were placed at such points as seemed to threaten most, and from time to time, as slides occurred, the road was operated with single track in that section, and large numbers of men quickly removed the encroaching talus. Several slides took place in the early spring of 1896 and again in the spring of 1897. The quantities decreased each year. A view of the slide of this spring, at the same point where occurred the greatest encroachment in '96 and '97, shows how surely the slopes are being reduced to an angle of

LOOKING UP RIVER FROM BELOW LEWISTON SUSPENSION BRIDGE, SHOWING GRADING.

repose and are taking on the appearance of stability. New vegetation adds greatly to their permanence and more agreeable appearance.

Coming out of Lewiston at the south line of the village is a timber trestle 104 feet in length and 42 feet high, crossing a small stream flowing into the river from the foot of the Lewiston escarpment. A little further up the line is a timber trestle carrying the tracks over a deep gully formed by another lateral stream, into which for many years the New York Central Railroad has wasted its surplus earth and rock. It was my intention to use eighty-foot girders at this point, but owing to the crowded condition of the bridge shops, delivery could not be secured in several months, and as the company was extremely anxious to open the road to catch the summer traffic, installation of the permanent structure was deferred. In the expectation that a large amount of water would filter through the talus, a great many open culverts were put in, but four years' experience has proved that the danger from this cause was overestimated. These culverts, to be effective, should be movable, as a boulder or other obstacle falling in the path of a stream high up on the talus will often divert the stream many feet from its former bed, and leave the culvert high and dry. The track is ballasted with rock borrowed from the talus over most of the line. The ties are of cedar, except on steep grades, where oak was used, and the rails, rolled by the Carnegie Steel Company, weigh sixty pounds to the yard. No attempt was made at mathematic alinement, as the road-bed followed the irregular outline of the natural slope.

Construction from the Buttery Elevator to the city of Niagara Falls was much more difficult than upon the lower five miles of the road. South of the elevator began almost vertical cliffs, extending from the top of the escarpment to the rapids below and continuing for a distance of about one-half of a mile to the Railroad Suspension Bridge. Drills and men were lowered over the cliff to the first ledge, about one hundred feet above the grade line, and blasting operations carried on mostly by hand, as it was difficult to get steam drills into position. The blasts were fired usually at noon, and huge quantities of rock were thrown into the river, disappearing beneath the tumbling waters of the rapids below, without appearing in any way to obstruct the stream or to change in the slightest degree the form of the waves. The vertical cuttings averaged nearly one hundred feet, and,

ROAD AROUND CLIFF NEAR PLATEAU.

estimated roughly, fully 100,000 cubic yards of rock were thrown into the river from this section.

At the site of the Van Horn Elevator a deep recess in the cliff formed a bay across which an attempt was made to construct a road-bed in the swift current of the rapids. This experiment I believed would be futile, as a powerful stream of water was constantly discharged upon the embankment, diverted from the main current by a high boulder of Niagara limestone resting in the channel about fifty feet from the cliff. It was evident that this bay had been excavated by the same powerful hydraulic agency, and it was useless to attempt to place in its way any structure less substantial than the cliff which it had cut out. During a period of extreme high water in the spring of 1897, when the river rose nineteen feet above its ordinary level, most of this embankment was washed away. In its place rough, but heavy, longitudinal walls were built to resist the encroachment of the current; spaces between the walls were refilled with stone and a stout timber trestle built to carry the tracks. In the spring of 1898 this structure was swept away, after which the company determined to do what it might profitably have done at first, and the old elevator-shaft was removed, the cliff blasted away, and a shelf made of sufficient width for a single track. Three timber cribs, each about sixty feet in length, protect the road-bed at critical points above this bay.

Beneath the railroad bridges a combination of difficulties was met. A small water-wheel under the Suspension Bridge, which furnished power for a flour-mill at the top of the bank, was rearranged to permit building the road-bed, the transmitting cable raised, and a portion of the tail-race changed and a retaining wall built to hold the embankment. Near this point is an inclined railway, the floor of which, resting directly over the center line, was raised vertically about fifteen feet. Between the incline and the cantilever bridge heavy walls were put in to hold back the loose rock on the inner side of the track, and retaining walls built on the outer side to prevent encroachment upon the head race.

Permission was obtained from the Michigan Central Railroad to build abutments on both sides of the cantilever-bridge piers and a central pier in front of and between their piers. The underlying material at this point is composed of very large boulders, upon which rest the foundations of the cantilever bridge, between which and

LOOKING DOWN GORGE BELOW WHIRLPOOL. SITE OF PROPOSED POWER-HOUSE.

the deep waters of the river there were but thirteen feet in which to pass. To prevent possible danger to the bridge foundations, blasting was prohibited within 100 feet on the south side and 50 feet on the north. No soundings could be obtained on account of the swiftness and great depth of the current. Within this limited area, hedged about by restrictions, construction was made doubly inconvenient.

From the bridges to the top of the high cliff, a distance of nearly a mile, the tracks are laid on a slowly ascending grade up the talus for about 3500 feet; thence entering the cliff and passing through a thorough cut 60 feet deep at the lower section, rising continually until the top of the bank is reached. The average gradient is $4\frac{7}{10}$, the maximum $6\frac{4}{10}$ per cent., and the total elevation overcome, from the bridges to the top, is just 200 feet. Passing beneath the New York Central tracks, the line swings sharply to the right and, paralleling the Central for a few hundred feet, reaches Second Street in Niagara Falls. At the southern end of Second Street connection is made with the Niagara Falls Street Railway and thence over the tracks of the latter company to Prospect Park. The under-crossing of the Central is made at an angle of fifty-five degrees; the bridge is of trough-girder type and carries at present five tracks.

I think you will grant that it was not practicable to make detailed plans for construction of this peculiar road. It was not possible to determine, with even approximate accuracy, how the unseen conditions might alter proposed methods. I can not say that any very serious engineering difficulties were met with, and I think there are no problems to be solved that will not be successfully met. The same vigor and energy which characterized the attack upon the ground were exhibited later in the effort to put the road in operation, and as gangs of men and construction tools would have been unsightly, work was suspended as suddenly as it was begun. You will recall the fact that wooden trestles and bridges had been put in place because the company was not willing to wait for permanent structures. The work was therefore left unfinished, but I was sustained by the vain hope that in the coming spring I should be permitted to scale down the slopes and replace the temporary structures.

When 1896 arrived all our efforts were concentrated upon construction above the Buttery Elevator, and this section, too, when nearly

EFFECT OF SLIDE, 1899.

completed, was given over to operation in much the same incomplete form as was the lower. It was expected that immediate earnings would be so great that a goodly portion of them could be applied to completion of the work, but receipts proved disappointing, and all further work was suspended, excepting such as was necessary to clear the track of slides and to provide for maintenance. As the outcome of business complications the owners of the road were obliged to relinquish it a few months ago, and it passed into the hands of a receiver. Reorganization of the company is now being undertaken, and I am engaged in making the necessary repairs, which amount to a reconstruction of the road, as considerable damage had been sustained by the track from slides and by the road-bed from the action of the river.

A fall of rock that occurred some weeks ago—accounts of which have appeared in the technical journals and in the daily papers, and called an avalanche—was greatly exaggerated. Before the road passed into the hands of the receiver I had recommended that some of the overhanging Niagara limestone just above the Buttery Elevator be removed by blasting, as it seemed to be insecure. The railroad was shut down; all people were warned not to walk upon the tracks, as it was intended before beginning operation to remove all overhanging rock which appeared to be dangerous. By reason of some blasting that was going on near by, within 100 feet of the point in question, where the city was excavating for a sewer, two large pieces of limestone were dislodged, falling between the tracks and the cliff without doing damage. A few days later our superintendent blasted and threw off into the river the large boulders, which now rest in the margin of the rapids just outside of the tracks. A considerable amount of loose material, of course, fell with the boulders and covered the road for a distance of about two hundred feet, a depth of from three to five feet. This was easily removed, and when taken away it was found that the rails were cut in several places, but that no great damage had been done, except to the lower portion of the shaft of the elevator, the casing of which had been carried away. Where these large rocks now stand in the river some difficulty had previously been found in maintaining the embankment, owing to the heavy current thrown against it, and a retaining wall about four hundred feet long had been resorted to for protection. With great good fortune these

large rocks now stand directly in the way of the heaviest attack of this current, and the retaining wall is no longer necessary. In general it may be said, in regard to falling rock, that it comes down only in the early spring months, when, under the new management, it is not intended to operate the railroad.

Since the opening of the road in 1895 to the present time no passenger or employee has ever received injury from falling rock. I was daily over the road during the construction, and have since been frequently from the Falls to Lewiston and return, both on cars and on foot, and have never seen a rock fall. It is my opinion that, with due care, the maintenance of this railroad need not be excessively expensive, and that the same safety of operation can be obtained as is secured on any mountain road.

There is no other electric railroad in the world that carries its passengers through scenery of such wild and rugged grandeur. The trip from Niagara Falls to Lewiston brings the traveler in the closest touch with the mighty Niagara. The whirlpool and the rapids, the crags and cliffs towering high above, combine to produce a spectacle as wonderful as the great cataract itself, and far more awe-inspiring to most visitors, whose emotions are well expressed by Howells when he writes, "One always experiences a vivid emotion from the sight of the rapids, no matter how often one sees them. . . . I had schooled myself for great impressions, but I had not counted upon the rapids taking me by the throat, as it were, and making my heart stop. I still think that the rapids are the most striking part of the spectacle."

DISCUSSION.

JOHN BIRKINBINE.—The paper just presented should have preceded the contribution which I made in January last upon the proposed water-power improvement in the gorge of the Niagara River, for without Mr. Ricker's work upon the railroad location and construction, the proposed water-power improvement would probably not have been considered seriously; but when it was possible to construct a canal, under an agreement to use the railroad right-of-way and to employ the road-bed as a berm-bank for the canal, the problem was simplified. It has been my privilege to traverse the entire route of the Gorge Railroad, and to walk over the portions of it which required the closest study, a number of times; and while doing this, the rock which lately fell, and which was illustrated by Mr. Ricker, was pointed out to me by him as being one that should have been removed.

To illustrate the topography of the gorge I exhibit some of the cross-sections made by Mr. Ricker for my use in calculating the quantities of material necessary to be handled in constructing the proposed water-power (a few indicative sections are shown by plate), which included removing the talus, and also the apparently dangerous overhanging rocks, as well as for cutting the prism of the canal. The sides of the gorge have been standing as cliffs for centuries, and the talus has been formed from slides (or avalanches, as some called them). But these do not come unexpectedly; at least, a critical examination will indicate probable falls.

The locality which Mr. Ricker indicated as having given him the greatest trouble, except in passing in front of the bridge abutments, is also the most troublesome for the water problem, as here the face of the cliff is vertical for nearly 240 feet, with only a small shelf close to the water level. It is near this point that the controlling entrance for the proposed canal is located, formed of a mass of concrete carrying large tubes. The canal project did not extend, and is not expected to extend, to the contracted section in front of the bridge piers, but starts below this, at a bay where the eddies have cut out the rock, and, in fact, undercut it so that it overhung the water. While the quantities of material to be handled are great, they can, as Mr. Ricker has shown, be gotten rid of cheaply. The blasting could be done in enormous masses, and but moderate care is needed, on account of the isolation of the gorge.

A passenger on the Gorge Railroad can, by glancing across to the Canadian side, form an opinion of the conditions as they existed before the engineer was lowered from the cliffs, and before he could take a sight with the transit or his assistant hold a rod on the talus on the American side. The gorge is not of so great a depth as some of the cañons in Colorado, but the conditions affecting the preparation of a road-bed are practically the same, with the addition of a raging torrent, which, for a portion of the distance covered, rushes by at the rate of 21¾ and 25½ miles an hour. These measurements, made at my request, while not exact, were taken from large floating objects, so that the approximate travel could be noted in the rushing steam. Through this narrow gorge, in places but 300 feet in width, is vented the outflow of the Great Lakes, exceeding at times 275,000 cubic feet per second.

Mr. Ricker has referred to the rise of the Niagara River, and it is interesting to note that this rise is not due to freshet, but to prevailing winds on the Great Lakes above the falls. A strong wind from the east will back up the waters on Lake Erie, and if this continues for several days, the amount of water passing over the Niagara Falls will be greatly diminished—so much so, in fact, that newspapers have proclaimed that Niagara was going dry; this we will never see. On the other hand, when winds prevail from the west, an increased volume of water may come down from the lakes, pass over the falls, and cause conditions in the Niagara gorge similar to those of a great freshet.

The accompanying map of the Niagara River between the Suspension Bridge and Lewiston indicates the course of the stream and the location of the Gorge Railroad. The short dotted lines show where the sections were taken, and the numbering of the sections also suggests the distance below the cantilever bridge,

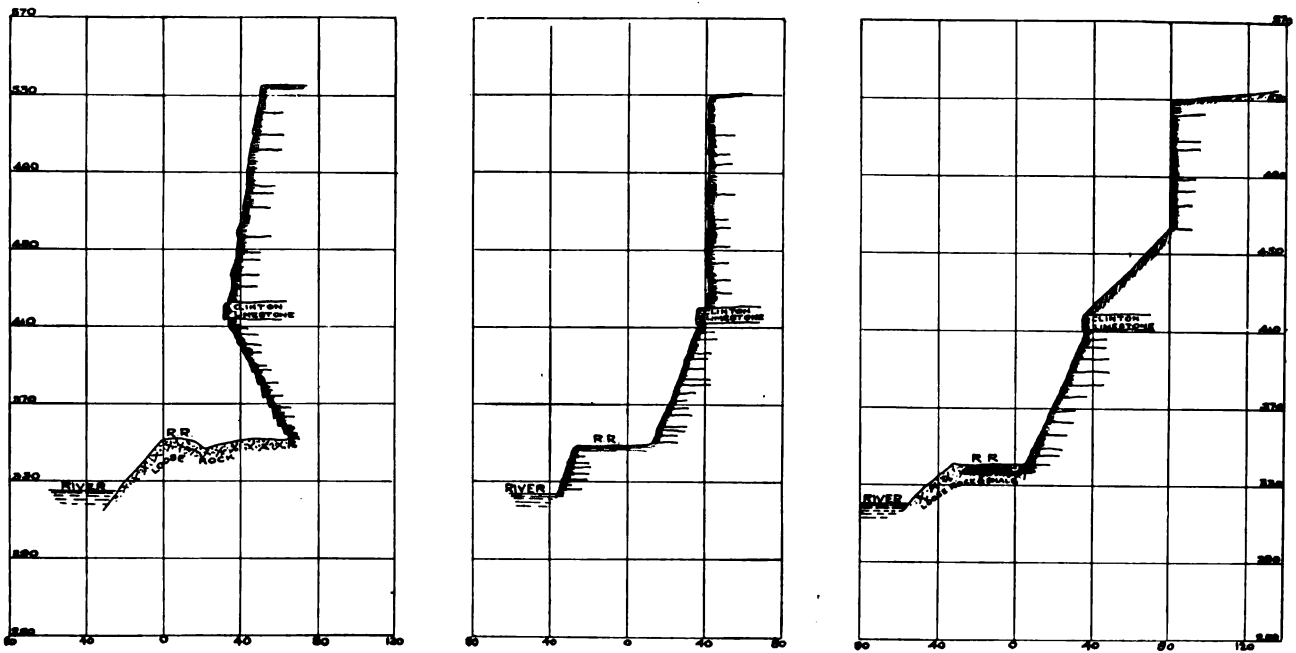
which is Section 50. Thus, Section 55 is 500 feet; Section 67, 1700 feet; Section 100, 5000 feet; and Section 149 is 9900 feet below the Suspension Bridge.

The twelve typical sections shown on the plates are indicated by rings surrounding the numbers on the plan.

MR. RICKER (in answer to questions).—The survey made in 1890 was something more than a preliminary. Several trips had been made in the nature of reconnaissance, and in 1890 the survey referred to was made, which, though not a location, was much more carefully made than an ordinary preliminary. There was but one place in which to put the line, so there could be no great change from the preliminary survey; it was, in fact, to all intents and purposes a location. As I have said, it was impracticable to follow the original profile on account of the insecure material that was found when the construction was actually begun. We did not attempt to form any road-bed in the rapids, except at the bay referred to. The experiment proved disastrous; the road-bed was entirely carried away. The inside track now rests upon a shelf excavated from the cliff, and the rock fill which carries the outer track is held in place by a crib. This crib is securely fastened by drift bolts to the ledge upon which it rests, and is anchored back to the cliff with rods. The large boulder referred to will be blasted out as soon as an opportunity offers, when the water is very low. In this way we will divert the heavy current which is now thrown against the crib. If this crib shows any signs of failure, we will put in a heavy masonry wall in its place.

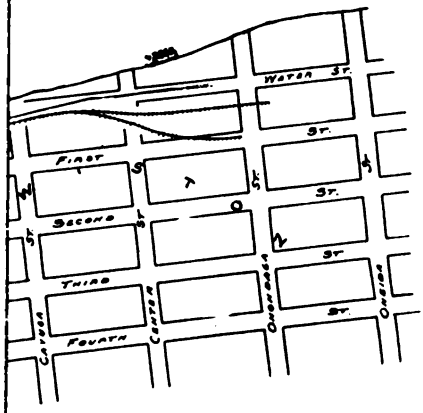
THE PRESIDENT.—You stated that this ledge goes below the water?

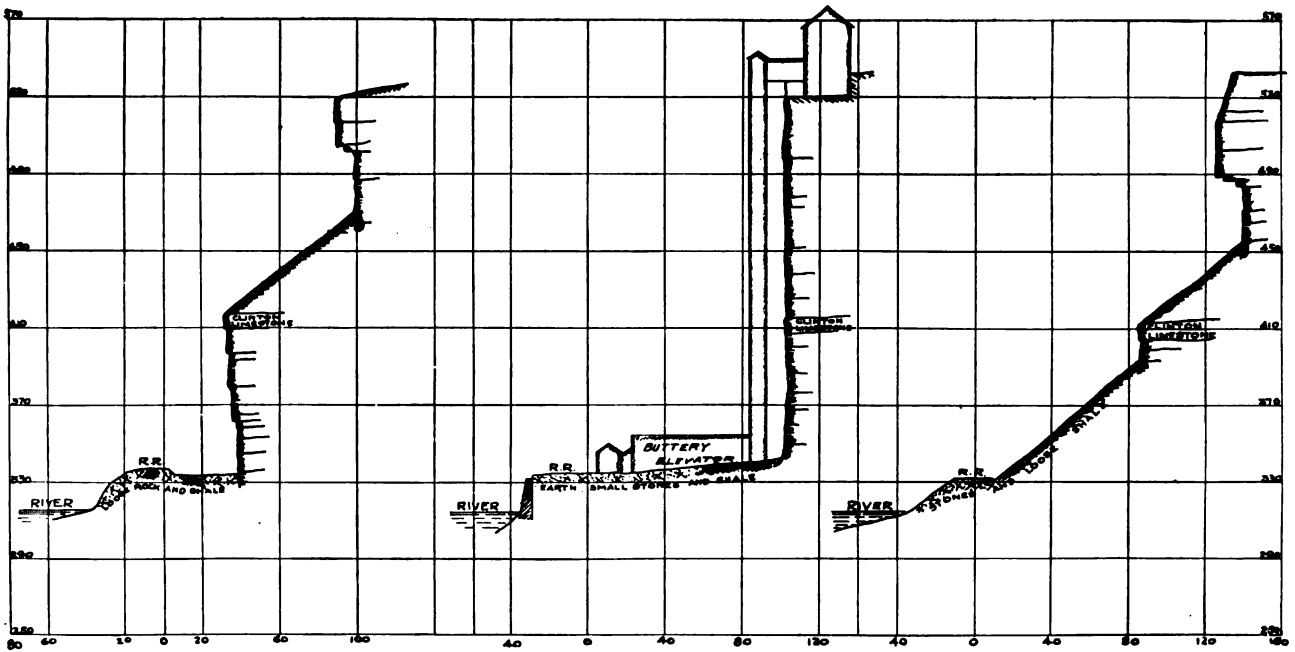
MR. RICKER.—Yes. At the ordinary level there are about two feet of water over the sandstone ledge upon which the crib rests.



Sec. 55. Sec. 58. Secs. 62 and 50.

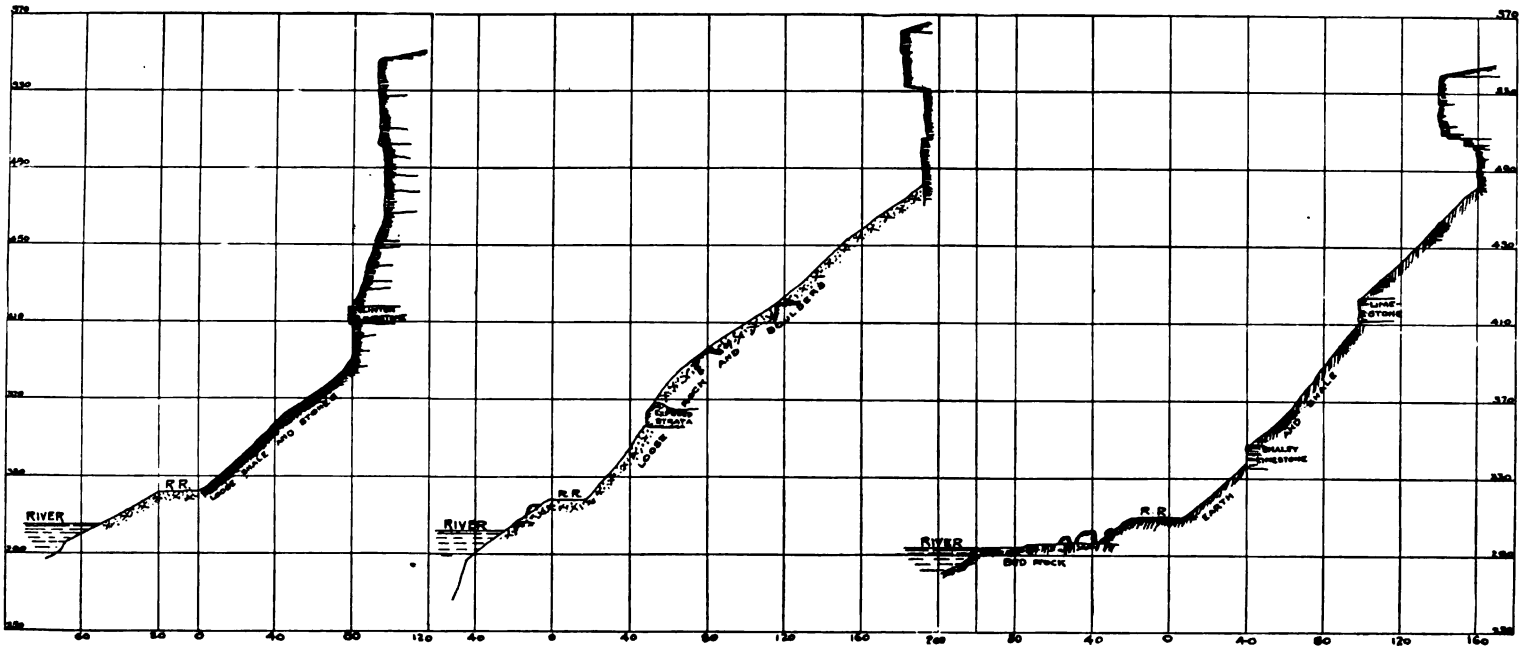
TYPICAL SECTIONS OF THE CLIFFS OF THE NIAGARA RIVER GORGE—AMERICAN SIDE.


Water St.
First
Second
Third
Fourth
St.
Cayuga
Center
Onondaga
Oneida



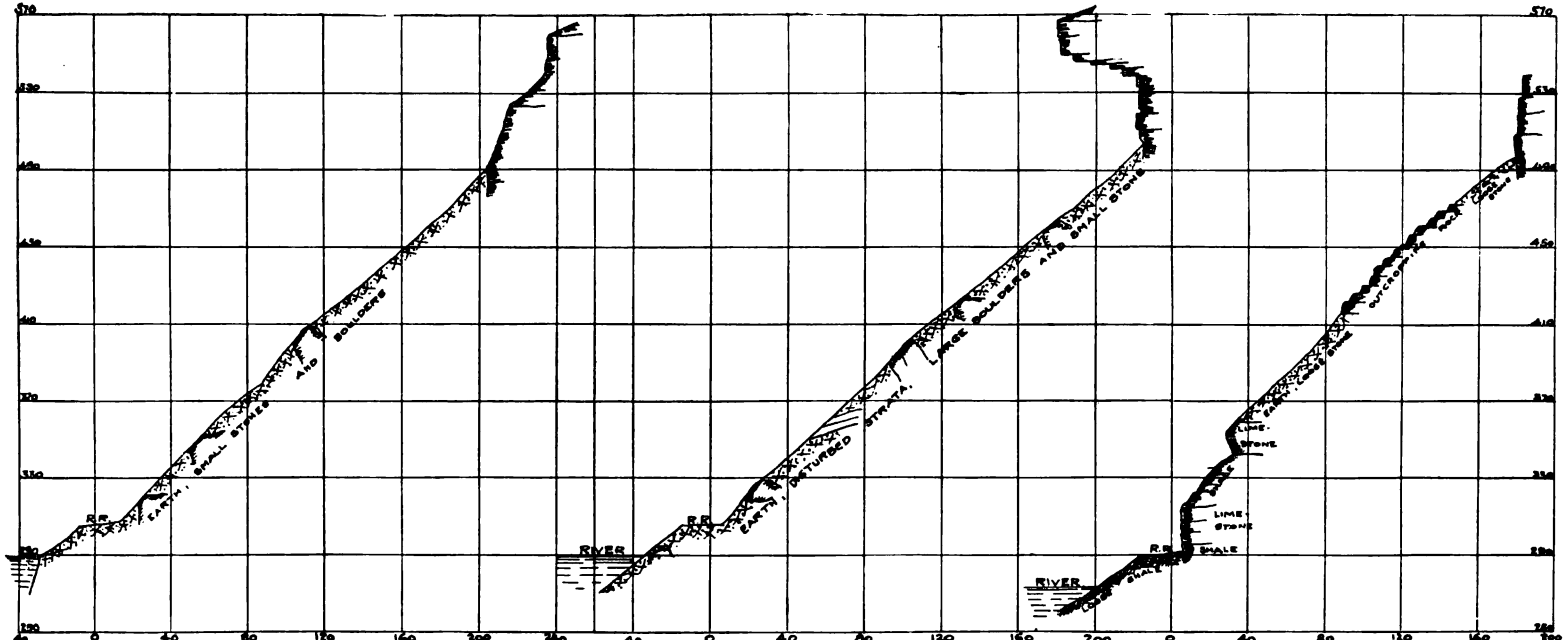
Sec. 65. Sec. 67. Sec. 70.

TYPICAL SECTIONS OF THE CLIFFS OF NIAGARA RIVER GORGE—AMERICAN SIDE.



Sec. 76. Sec. 88 Sec. 100.

TYPICAL SECTIONS OF THE CLIFFS OF THE NIAGARA RIVER GORGE—AMERICAN SIDE.



Sec. 108. Sec. 112. Sec. 149.

TYPICAL SECTIONS OF THE CLIFFS OF THE NIAGARA RIVER GORGE—AMERICAN SIDE.

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, May 6, 1899.—The President in the chair. Sixty-seven members and eight visitors present.

A memorial of the late James McCann was read.

Mr. Harry K. Myers read a paper on "Modern Mine Haulage Practice."

The subject was discussed by Messrs. Richards, Hewitt, Hering, Webster, Nichols, Christie, Souder, and Schumann.

The tellers reported the election of H. H. Cooke, Emile Geyelin, C. J. Reed, W. S. Vaux, Jr., and William Warr to active membership, S. H. Harrison and G. P. Robinson to junior membership, and F. E. Bailey to associate membership.

REGULAR MEETING, May 20, 1899.—The President in the chair. Fifty-seven members and six visitors present.

A topical discussion on "The Utilization of Waste" was opened by Mr. John Birkinbine, and was continued by Messrs. Livingston, McBride, Christie, Souder, Little, and Fairchild.

Mr. Birkinbine also exhibited and described a number of lantern-slides relating to the buildings of the National Export Exposition to be held in Philadelphia in the autumn of 1899.

BUSINESS MEETING, June 3, 1899.—The President in the chair. Forty-nine members and nine visitors present.

Mr. George A. Ricker read a paper on "Building the Niagara Gorge Railway."

The subject was discussed by Messrs. Birkinbine, Christie, and Schumann.

The tellers reported the election of William R. Dunn to active membership, C. Shuman and J. H. Stitzer, Jr., to junior membership, and James Thompson to associate membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, May 20, 1899.—Present, the President, the Vice-Presidents, Directors Humphrey, Smith, Levis, and Souder, and the Secretary.

The Treasurer's report showed a balance, April 30, 1899, of $2334.59.

The resignation of W. D. Zehnder was accepted, to date from December 31, 1899.

SPECIAL MEETING, June 3, 1899 (called to take the place of the regular meeting of the 17th instant, to be omitted by agreement).—Present, the President, the Second Vice-President, Directors Humphrey, Ott, Smith, Evans, and Levis, the Secretary, and the Treasurer.

The Treasurer reported balance on hand of $2523.48.

SPECIAL MEETING, June 17, 1899.—Present, the President, the Vice-Presidents, Directors Humphrey, Evans, Levis, and Souder, and the Secretary.

The meeting was called to consider the report of the Committee on Rules. The Special Committee reported a series of rules which were adopted for the future government of the Board and its committees.

The subject of proposed changes in the arrangement of some of the rooms in the Club-house was discussed, but no decision as to specific changes was reached.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XVI. OCTOBER, 1899. No. 5.

COASTAL TOPOGRAPHY OF THE UNITED STATES.

OSCAR C. S. CARTER.

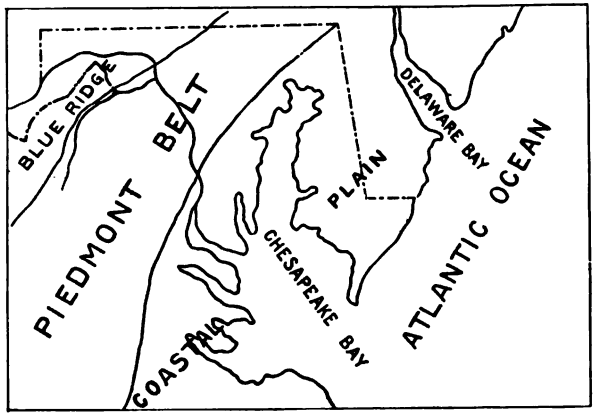
Read April 15, 1899.

IT is my purpose this evening to speak of the coast-line of the United States and the topography of the coast-line; to speak of it in a general way at first, and afterward illustrate special portions of the coast-line by means of slides. If you will examine a map of the coast survey of the New England coast you will find scores of islands off the coast of Maine. There are more than three hundred of these islands, and they can not be shown on the small maps. These islands are regarded as merely submerged portions of the coast-line; that is, submerged hills. As a general rule, the rock on the shore-line of the island and on the opposite main shore-line is of the same composition. There are not only hills, but also drowned river valleys. That indicates, of course, the submergence of the coast-line. When the entire northern portion of British America and the New England States was covered with the ice sheet, New England was buried about a mile deep. The tops of the White Mountains were entirely covered. The Adirondacks then stood out as islands in the sea of ice. The terminal moraine, as you well know, passes across Pennsylvania. Now, if the tops of the White Mountains are striated and grooved by glacial scratches, New England was buried about a mile deep under the ice

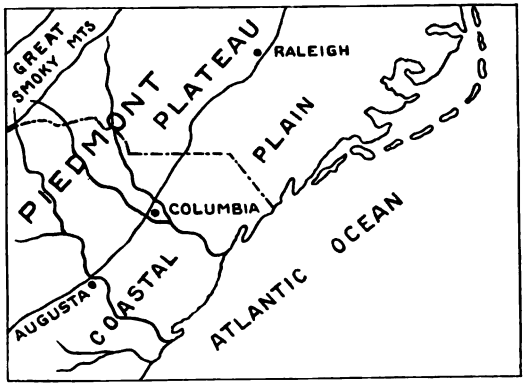
Bar Harbor from Summit of Green Mountains.

sheet. It is supposed that the pressure of that enormous mass of ice caused one subsidence. There have been alternate subsidences and elevations along the New England coast. After the ice sheet melted and receded the pressure was relieved, of course, and then again there was elevation; but after that elevation there was again subsidence, and probably during that subsidence these hills were drowned. The hills of New England are the stumps, you might say, of a worn-down mountain system. The peaks were very high at one time, but they have been worn down by erosion to their present elevation, and these hills gradually extend out to the sea. Now, when we get as far south as Nantucket, which is an island located about thirty (30) miles off the coast of Massachusetts, we come to a different type of island altogether. That is a sandy island, as is also Martha's Vineyard, Elizabeth, Block, and even parts of Long Island. I will speak of these islands more in detail when we come to that part of the subject. I will explain them more in detail by the slides, and will merely say now that these islands are entirely different from the islands off the coast of Maine. They are made up mostly of sands, clays, and gravels. They are not rocky islands. The sandy coastal plain begins below Long Branch and extends across southern New Jersey.

This map is taken from the fifth annual report of the United States Geological Survey, and is used merely to show the limits of the true coastal plain, which can be traced out by this dark line. The true coastal plain runs from the mouth of the Hudson to the Rio Grande, including half of New Jersey, nearly all of Delaware, two-thirds of Maryland, two-fifths of Virginia, about one-half of North Carolina, about one-half each of South Carolina and Georgia, and the northern half of Florida, three-fifths of Alabama, nearly all of Mississippi, all of Louisiana, and one-quarter of Texas, and parts of other States. The sandy portion begins right below Long Branch. This portion was at one time under the ocean. It is a country of sands, marls, and clays essentially, and the line here marks the line of contact between the coastal plain and what is known as the Piedmont plateau; in other words, marks the line of contact between this country of sands, marls, and clays and the rocky plateau beyond, and it is also an important cultural line. Most of the important Southern cities are located along this line of contact between this inland coastal plain and the Piedmont plateau, because it marks the head of navigation. For



PIEDMONT BELT AND COASTAL PLAIN OF VIRGINIA AND MARYLAND.



COASTAL PLAIN OF THE CAROLINAS.

example, as we go south from Trenton to Raleigh, Columbia, Augusta, Macon, Columbus, Montgomery, Tuscaloosa, Little Rock, Arkadelphia, then across Texas to San Antonio and Austin, we see these are nearly all important Southern cities; and one reason why they are important is because they mark the line of falls where there is excellent water power, and from the fact that the sandy coastal country extends to this point. You can readily see that the rivers have cut their course through this rocky Piedmont plateau, which is situated between the coastal plain and the Appalachians; they have also cut through the Appalachians, and some even as far west as the Allegheny plateau; they have cut their channels through the mountains, but when they come to this country of sands, clays, and marls, there must necessarily be falls, because the rivers wash away the clays and sands, and naturally the falls would be at these cities which I have mentioned; hence they are at the so-called fall-line, and the rivers are generally navigable to these cities.

Of course, above, on the Piedmont plateau and beyond it, are numerous cascades and small waterfalls, as you would naturally expect in a rocky country. We have along the coast the Delaware and the Chesapeake and also Albemarle and Pamlico sounds. They are merely submerged river valleys. Before this section of the country subsided, the rivers cut through and made those large V-shaped valleys. Of course, the rivers cut these valleys, but they became V-shaped valleys by erosion, which widened out the valleys at the top; all the various forces of erosion—the atmosphere, the freezing of water, frost, and, in fact, every erosive agent—are active in widening a valley. A large valley V-shaped is a sign of age. A trench-shaped valley (⊔) is a sign of a young river. Now, when this section of the country subsided it simply drowned this river formation and made these broad estuaries of the Delaware and Chesapeake and Albemarle and Pamlico sounds. The sounds of Albemarle and Pamlico are very shallow, and they are surrounded, as you well know, by sand bars. These bars have been formed by eddy currents moving toward the southwest between the Gulf Stream and the mainland, and they have driven the sand up into these long bars, generally concave on the outward side and smoothed and worn even by currents.

A series of lagoons stretches all the way along the entire eastern

coast from New Jersey down to the end of the peninsula of Florida. It has been said that a man could travel in a small boat from Norfolk, Va., all the way down to the Bay of Biscayne in Florida simply by passing through these lagoons and not travel the main ocean at all. There would have to be a few portages. This gave rise to the suggestion of a ship canal from Norfolk Point down along

BEACH AT ROCKLEDGE, INDIAN RIVER, FLORIDA.

the coast to Florida through these lagoons. It can not be shown well on this small map; there is a lagoon along the eastern coast of Florida known as the Indian River; in reality, it is simply a long lagoon, not a river. Along the coast of Florida, along the western coast in particular, there is only about one good harbor—Tampa Bay. That extends inward for about thirty miles and is twenty-five feet or more in depth; so it allows passage for the largest vessels. A town, Tampa, has sprung up there which rivals now in

importance Jacksonville. It is also an important point from the fact that valuable phosphate beds are very near this harbor.

Passing along this Gulf coast we finally come to the coast-line of Texas. That is a new coast-line that was recently uplifted and is little dissected, like the Florida coast. You can readily see that the ocean distributes the sediment regularly and evenly along the bottom; hence if the coast-line should become elevated, a new and comparatively even line would be exposed, which would become more uneven and dissected as it grew older. This Gulf coast-line along Texas and Florida is given as an example of recent coast-line. From the Rio Grande northward there is a sand bar which extends for 100 miles, the longest sand bar of which we have any knowledge.

In speaking of the coastal plain, I have so far neglected to say anything of the submerged coastal plain. As you well know, the water increases in depth very gradually as you go outward from the eastern coast of the United States; in fact, only five or six feet per mile. If you were to travel, say, 100 miles off from Sandy Hook, the 100-fathom line would be reached at a distance of about one hundred miles off shore. Now, the fall is said to be, according to the Coast Survey, only five or six feet per mile. Suppose this section of the country should be elevated now: there would be such a slight fall that it could not be detected with the eye. It would be impossible to detect the slight slope; it would look to us like a perfectly level plain. Whenever there are any wrecks near shore, the masts will stick out above the surface of the water. The hydrographic map issued monthly by the Government for use of mariners shows these wrecks. This continental platform is rather irregular in extent, but the distance from the shore varies from, say, fifty to one hundred miles, and the ocean is only 600 feet deep at the end of the platform. There is a continental platform in the Gulf of Mexico that extends out a little farther from shore than the width of Florida. We have this continental platform along the eastern coast of the United States. At the end of the platform the abyssal depths of the ocean are reached, as the descent is very abrupt. The depth of these beds of sand along the coastal plain is not known. At Ocean Grove and Atlantic City, N. J., artesian wells 600 feet in depth have been bored, passing through alternate beds of sand and clay. The bed-rock lies probably many hundred feet deep. Leaving the eastern coast and passing over to the coast of

the Pacific, the absence of sand bars is at once noted. There are scarcely any sand bars along that entire coast; the infrequency of sand bars along the Pacific coast is due to the greater depth of water; the continental shelf is imperfectly developed along the Pacific slope. Another fact that impresses us is the great scarcity of islands off the Pacific coast. There are a few off the southern coast of California, namely, Santa Barbara, Catalina, and a few others, evidently submerged portions of the coast-line, hilly, just like the mainland, There are practically no islands and an entire absence of sand bars whereas along the eastern coast of the United States it is exactly the reverse. Another point is the scarcity of good harbors. For a distance of 1200 miles, from San Diego north along the coast of California, Oregon, and Washington, there are only about three good harbors: a fairly good harbor at San Diego, and the coast range of mountains is dissected at the Golden Gate, at San Francisco (that is the only place where this range is dissected), a good harbor at the Columbia River, and also north at Puget Sound.

The reason of this scarcity of harbors is a matter of some little question, but the opinion seems to be that the river valleys along this coast are above the ocean quite a considerable height; and another reason is they are young streams, and have not cut down very deep valleys. They are entirely different and distinct from the streams in the East. The Delaware, Susquehanna, and Potomac are older than the Appalachians. They were flowing before the Appalachian Mountains were elevated, and they have cut deep gaps, as shown by the Delaware at Delaware Water Gap, the Schuylkill at Port Clinton, and the Potomac at Harper's Ferry. All of these rivers along the east coast which rise in the Appalachians are old rivers, but those along the Pacific coast which have their source in the Shasta and coast mountains are comparatively new and are small. That I give as the reason why there are few harbors along the Pacific coast in California. There has been no subsidence of any account. The elevation of the valleys is high above the coast-line.

Here is a recent map of the United States Geological Survey, issued in 1897, to show the coast-line of Alaska. The coast-line, of course, is much better known than the interior. This map was prepared from chart "T" of the Coast Survey, and it is shown to call attention to the fact that along this coast-line of Alaska we have numerous

drowned hills, due to the submergence of the coast-line, and there are many drowned river valleys. In fact, the journey from Seattle to Sitka can be made by winding in and out among these drowned hills and not ever going out into the ocean. This coast-line resembles the coast-line of Norway and Sweden, and, to a certain extent, the coast-line of Maine. This heavy line represents the boundary between the British possessions and the American, and the various trails to the Klondike are shown. Elevation and subsidence are always taking place on some portion of the globe. For example, the northern part of Norway and Sweden is rising and the southern part sinking. The vicinity of Stockholm seems to be the pivot, so to speak. These facts were denied by European geologists, but the Swedish geologists went carefully over the ground again, erected monuments along the shore-line, and proved the correctness of their views. The fiords in Norway are drowned U-shaped river valleys, made U-shaped by the glaciers which filled them during the glacial epoch. Rivers originally cut these valleys V-shaped, but the ice widened the bottoms. The island of Candia lies south of Greece; one end is rising and the other end is sinking. At Washington, D. C., in colonial times the vessels came to the wharves of the suburban towns to get tobacco to take to London. Now the water is so shallow they could not get near the wharves. This is not due to the rivers filling up with silt, as they have rocky bottoms. McGee says it is due to elevation. The coast of Greenland is slowly sinking. The statement has been made that the Esquimaux are acquainted with this fact and never build their houses too near the shore-line. Whether this be true or not, subsidence is not to be wondered at when we consider the fact that the greater part of Greenland is covered with an ice mantle two thousand to three thousand feet thick.

The greater part of the coast-line of the United States is a sandy beach; in fact, we have a sandy beach-line from Long Branch to the Rio Grande. These sands are continually shifting and working their way farther south. The sands along the coast of Florida have been shifted many miles from the north, beyond Cape Hatteras. This fact is not difficult to understand when we consider the fact that our eastern coast-line is not straight, but trends from the northeast to the southwest; hence, when the waves meet the coast-line, the sand is pushed farther south, and carried by the southward-moving currents

running between the Gulf Stream and coast. The beach sand of Nantucket is coarser than that of Atlantic City, while that of Atlantic City is a trifle coarser than southern beach sand; but after sand reaches a certain size the attrition is slight, and it changes very little; the water between the grains acts as a cushion and prevents or lessens friction. There is a great deal more friction and rounding of the grains when sand is blown across the dunes. If we examine a handful of beach sand, we shall find, as a rule, that it is composed almost entirely of grains of quartz, sometimes transparent, often colored yellow by iron. It makes little difference where we take the sample, whether it be from the New Jersey or Florida beach, it is quartz sand. At Atlantic City there are layers of black sand mixed with the quartz; these are often mistaken for grains of magnetic oxid of iron; they are, however, simply fragments of black shells ground fine by the waves. Black grains of magnetite will not last long in sea-water; they will finally go into solution.

Origin of Beach Sand.

The rocks along the New England coast are generally igneous or metamorphic rocks. Granites, gneisses, and mica-schists are common. If we take a handful of old beach sand and examine it under a hand lens, or even with the naked eye, we will find that it is made up of grains of quartz, sometimes more or less rounded. These quartz grains are hard, and practically insoluble in water except under certain conditions. We know that hot water containing the alkalies soda or potash will dissolve silica, and that certain soluble silicates of soda or potash find their way into solution in water when rocks containing feldspar and mica decompose. But quartz as a mineral may be considered practically insoluble in water. This accounts for our sandy beaches; the sand of rocks is insoluble, and hence forms our beach sands. If a coast-line exposed to the waves were a jointed sandstone, we can readily understand how, when the rock is weathered and disintegrated by the wave action, a sandy beach will result, because a sandstone rock is simply made up of grains of quartz sand held together by a cement. The cement varies; it may be clay, iron oxid, or calcium carbonate. When the cement is loosened the grains fall apart. The rocks along the New England coast, however, are generally granitic, and the sandy beaches result as follows: Granite is a rock composed

of three minerals—quartz, feldspar, and mica. When this rock weathers along the coast-line and the waves dash it to pieces and grind it fine, the feldspar and mica gradually decompose, the soluble parts of the rock dissolve in the sea-water, and the clay which results is spread out over the bottom or carried seaward by currents. The other constituent of the granite, quartz, remains and forms the beach sand; it may be coarse at first, but it is gradually ground finer. In a new beach sand at the base of a granite bluff we will find mica and feldspar grains mixed with the quartz sand, but the mica and feldspar soon disappear; they are softer than the quartz and are soon ground very fine, and finally decompose and partly dissolve, and are carried seaward, so that only quartz sand remains. A beach sand from as far south as Atlantic City will show only quartz sand; the other constituents disappeared farther north along the beach.

Maine.

The coast-line of Maine, with its drowned hills and valleys and its numerous fiords and bays, is similar in many respects to the coast-lines of Alaska and Norway. The drowned river valleys and the numerous bays furnish plenty of excellent harbors. There is no State in the Union so deeply indented by bays, fiords, and other inlets; the indented coast-line measures 2500 miles, but in a straight line it would measure only 225 miles. The low islands are wooded and grassy, but many of them are rugged cliffs; between these islands and certain parts of the mainland the water is deep enough and there is room enough to float the navies of the world, but the larger vessels could not get near the island of Nantucket to the south on account of shoal water. The erosion of a rocky coast-line like that of Maine depends to a great extent on the kind of rock and the way it is exposed to the ocean; if the country rock be stratified and the strata dip or slant toward the ocean so as to present their faces to the waves, then erosion will be slower, because the waves dash up the slope, and as they return they meet an ascending wave and the force is broken. Erosion is most rapid when horizontal or inclined strata are presented to the waves.

I recall the experience of a man at Atlantic City who owned a valuable property along the beach. He had bought the riparian

PATH TO THE "WRENS," FRENCHMAN'S BAY.

rights from the State, so that whatever ground is made by the ocean receding belongs to him, otherwise it reverts to the State, and could be sold to another party, who might shut off his ocean view. This man tried to protect his property from the waves by sinking cedar posts in the usual way and filling in between them with rock. One night a heavy storm arose and the waves dashed the bulwarks to pieces. His next plan was to copy from nature and slant heavy planks toward the ocean in the same way that rocks sometimes dip; this plan was successful, because during a heavy storm the waves simply rushed up the slope and the force was broken. His property is still thus protected.

These views illustrate typical coastal topography of Maine, not only along exposed shore-lines, but in more or less sheltered spots, like Frenchman's Bay and Bar Harbor. One can often tell if a view rep-

In title of illustration, for "*vorens*" read "*ovens.*"

rock. The underlying rock may be a mica-schist and the erratic boulder granite. Such boulders have been transported in the ice when the country as far south as Pennsylvania was buried under the ice sheet. The northern hills are covered with them. Even as far south as the Delaware Water Gap we find a block of Helderberg limestone on the mountain-top entirely different from the hard, underlying rock; this boulder was probably torn from an outcrop in New York State and carried south. In the State of Iowa boulders of Lake Superior copper rock are found. From personal inspection of these rocks, holding native copper, and comparison with those from the Calumet and Hecla mines, I am sure they can not be mistaken for any other rocks. The amygdaloids, traps, epidotes, and jaspers, holding native copper, are characteristic, and they have been transported from the shores of Lake Superior to Iowa. The terminal moraine of the

glacier did not reach as far south as Philadelphia, but passed through Belvidere, N. J. The moraine has been traced across Long Island, New Jersey, Pennsylvania, Ohio, Kentucky, Indiana, Illinois, Missouri, Kansas, Nebraska, and Dakota.

Sandy Islands.

Leaving the rocky islands off the Maine coast, some of the sandy islands off the Massachusetts coast will be considered. Nantucket,

Harbor of Nantucket.

Martha's Vineyard, Elizabeth, and Block Island belong to this class. These islands to a certain extent, not altogether, are made up of morainic material. They also contain cretaceous and tertiary sands, clays, and gravels. They were evidently at one time connected, for the formation is somewhat similar and there is shoal water between them. At one period they were also connected with the mainland. As I have a series of views to illustrate the topography and geography of Nan-

tucket, it is best to take this island as a type and describe it in a general way. The island was discovered in 1602 by Bartholomew Gosnold. It was then inhabited by about seven hundred Indians; the last descendant of these died in 1822. It lies about thirty miles southeast of Cape Cod and is bounded on the north and west by Nantucket Sound and on the south and east by the open Atlantic. It is reached by steamers from New Bedford stopping at Wood's Holl. In

JETTY AT NANTUCKET.

1641 it was deeded to Mayhew & Son by Lord Sterling. It was afterward sold for thirty pounds and two beaver hats—somewhat of a bargain, when we consider that the island is about eighteen miles long and its width is from five to eight miles. When discovered it was covered with forest trees, mostly oaks, and some pines, which have been cut down. No strips of woodland of considerable size are now seen; the trees are small and stunted and seem unable to thrive or gain a good foothold. There are strips of scrub timber four or five feet high, which have not

materially changed in size for the last ten years. The strong east wind during the winter probably influences the growth. The island is of low relief; the highest elevation is probably not over sixty feet above tide. There are wide stretches of moor and meadow, which have a flora peculiar to the district. The gorse, broom, and three varieties of heather are found. Some of the swamps are bordered by

GLACIAL BOULDER AT NANTUCKET.

orchids; wild roses and azaleas are common on the moors. Nantucket was formerly an important whaling station. In 1820 there were seventy-two ships engaged in whale fishery. They usually made a four years' cruise, each man getting a portion of the oil as his share. The population in whaling days reached 10,000, but it has dwindled down to about 3000, which largely increases during the summer, as the island has become a favorite watering-place, on account of the perpetual sea-

breeze. The town of Nantucket is on the harbor, and the characteristic frame houses are little different from most New England houses. They are surmounted, however, by roof porches, known as widows' walks. As the vessels made long cruises, the relatives of the sailors were naturally anxious to notice the first approaching ship in the harbor, and they kept watch from the porticos on the tops of the houses; hence the name. On account of the shoal water, no large cruiser can enter the harbor at Nantucket, and during the war with Spain some anxiety was felt at first on account of the unprotected position of the island, but it is said that large naval cruisers could not get within five miles of the island. As the harbor was in reality a small bay with a narrow entrance, the Government engineers decided to deepen the channel by building a jetty from each side of the entrance, the idea being that if the entrance was narrowed the tide would scour out the sand and deepen the channel. This was a considerable undertaking, as there is no bed-rock on the island, only an occasional glacial boulder. The rocks to build the jetty were brought from Connecticut; large boulders of granite, weighing ten or twelve tons a piece, were dumped in a straight line from the shore for a distance of nearly a mile, and from the opposite shore the other line of rocks extended out, leaving the narrow channel between. This jetty cost $200,000. The channel has been deepened to a considerable extent, but not so much as was expected. The excellent supply of pure water for the town is drawn from one of the numerous ponds, which have a natural lining of tertiary clays. The water is well filtered, as it has filtered through the natural sand beds or hills at a higher elevation. Nantucket Island on the south and east, where it is exposed to the full force of the ocean, is being cut away at the rate of twenty or thirty feet per year. A hotel was built some years ago several hundred yards from the ocean, but the erosive action of the waves has been so great that now the hotel is near the water's edge. We would scarcely expect to-day to find a place where there is a town-crier, but on this island there is a man who cried the news of the Civil War and also that of the late war with Spain.

Coastal Plain.

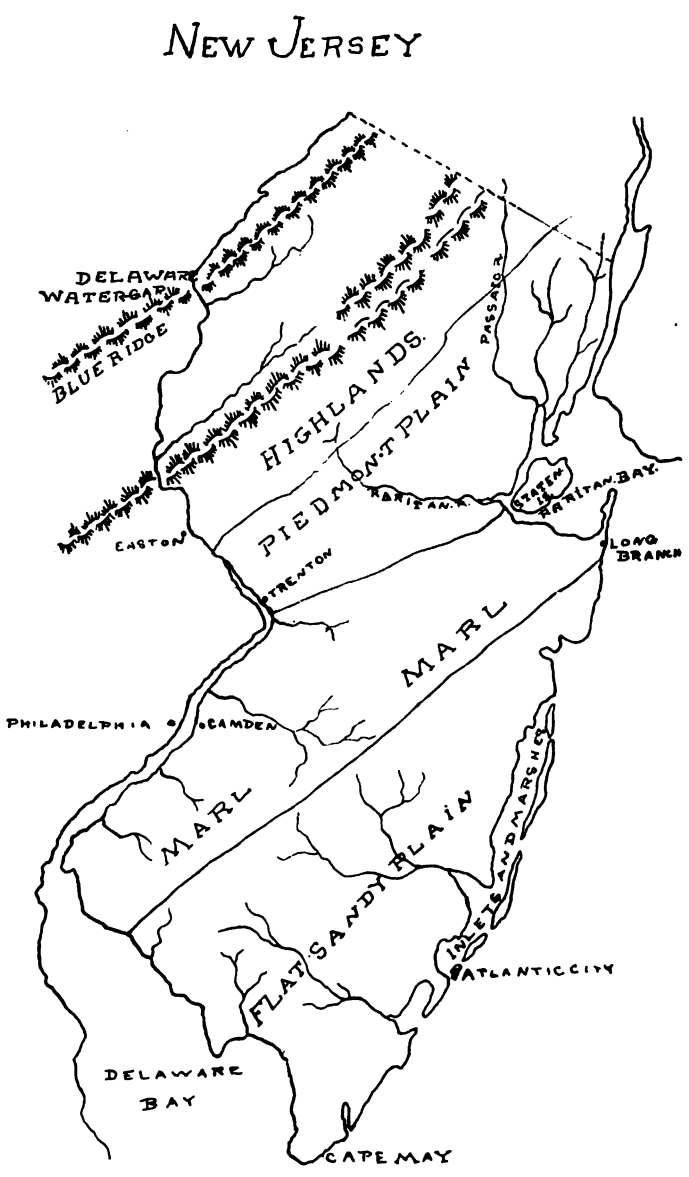
The coastal plain of the United States is of such enormous extent that it would require too much space to describe it; so I will select a

typical strip and describe points of general interest. Northern New Jersey is a rocky country, in which are found (1) the Kittatinny mountains and valleys, belonging to the Appalachians; (2) the Highlands; (3) the Piedmont plain. In southern New Jersey we find a characteristic strip of the coastal plain. When we travel from Philadelphia to Atlantic City we pass over what is known as the Atlantic coastal plain, a low, sandy tract of land which comprises all of southern New Jersey. It may be divided into the marl belt, the hilly belt, and the sandy plain.

Marl Belt.—Leaving Camden, the road soon enters the marl belt. Marl is a greenish earth made up of shells and clay; the lime of the shells makes it a valuable fertilizer for grasses and cereals. Some of the marl belts are fifteen miles wide and vary in thickness from two inches to twenty feet. These beds are full of fossils. The marl is found in a strip of land extending from Raritan Bay and the Atlantic southwest to the Delaware River. Monmouth County has furnished 100,000 tons per year. In the so-called marl belts are found valuable deposits of clay, from which china, earthenware, and bricks are made. At Trenton high-grade American china is made. After leaving the marl belts the hilly belts are reached.

Hilly Belt.—The hills are of but gentle elevation; most of the numerous creeks which empty into the Delaware have their source among these hills. They act as a water-shed, and separate the streams which flow into the Delaware from those which flow into the Atlantic Ocean. In the marl and hilly belts we find the best farming land of New Jersey. There is an abundance of fertilizer near at hand, and the truck-farms are near enough to furnish the Philadelphia markets with vegetables.

Sandy Plain.—Between the hilly belt and the ocean stretches the long, low, and level sandy plain. Here the soil, on account of the sand, is unusually poor and in marked contrast with the other belts. The farms are few and far apart, and the greater part of the plain is covered with unbroken pine forests, which often stretch for miles. These pine forests are often of second growth, and are covered with dense undergrowth, where high ferns, commonly called brake, grow in luxuriance. The rivers which flow into the Atlantic flow sluggishly along through this sandy plain. There are no falls, where water-power can be utilized by manufacturers, as in the State farther north and


NEW JERSEY
DELAWARE WATERGAP
BLUE RIDGE
HIGHLANDS
PIEDMONT PLAIN
PASSAIC R.
RARITAN R.
GREEN R.
RARITAN BAY
EASTON
TRENTON
LONG BRANCH
MARL
PHILADELPHIA
CAMDEN
MARL
SANDY
FLAT
INLETS AND MARSHES
ATLANTIC CITY
DELAWARE BAY
CAPE MAY

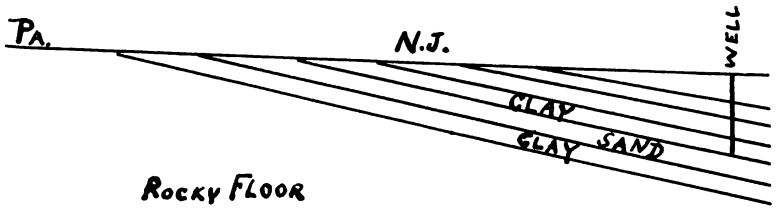
west. Marshes form near the low river-banks, caused by the overflow, and on the swampy soil cranberries are grown. The railroads on the sandy plain are the shortest lines joining two given points; the cars run as the bee flies—in a direct line to its home. Whenever we examine a handful of sand from the various inland points along the plain, we see at a glance that it is ocean-sand. The sidings from

Sand Dunes, New Jersey.

the main line of railroads often run up to gravel banks, which are miles away from the shore; the gravel is loaded on cars and taken to Atlantic City, where it is used to macadamize the sandy roads, as there is no bed-rock exposed in southern New Jersey. These gravel beds tell an interesting story. They are beach-lines of former ages, when the pebbles along the beach had their sharp corners worn off by the action of the waves. When the ocean receded it left them high and dry·

At Pleasantville we arrive at the present shore-line, or shore-line proper, which is higher than the series of islands and lagoons to the eastward. That the coast-line is higher can be better seen when we travel homeward from Atlantic City across the meadows.

Lagoons and Islands.—When we look oceanward from Pleasantville, which is but a couple of miles from Atlantic City, we see a series of low, flat marshes and islands. The lowland above the marshes is popularly known as the meadows. The railroads are built on an embankment higher than the meadows, but during severe storms the ocean-water often covers the tracks, and communication is shut off between Atlantic City—which is built on an island—and the mainland. When creeks empty into the marshes the water is brackish from the admixture of salt water, otherwise the water of



IDEAL SECTION, SHOWING ARTESIAN-WELL HORIZONS IN ATLANTIC COASTAL PLAIN.

the lagoons is salt. When we journey along the islands from Atlantic City to Longport we notice that the coast topography is different from that of the coast-line proper. At Pleasantville, below Atlantic City, we notice mounds of sand thirty feet in height, known as sand dunes. They have been heaped up by the strong east winds which blow from the ocean. These dunes are covered with cedars or pines, and none of these trees are symmetric, like those farther inland. The tops are bent over and point toward the west, thus showing the force of the east wind. If we stand on the iron pier at Atlantic City and look along the coast in a southeasterly direction toward Longport, we see that the ocean has cut a wide swath into the land, and the coast-line makes a strong bend inland, and the sea is encroaching more and more; but while land is being lost in the southern part of Atlantic City and below, it is gained in the northern part of the city. Not many years

back the ocean beat against the base of the light house at Atlantic City, and there was much fear the lighthouse would be damaged. Everything that could be used was put near to hold the sand. Now there are a couple of squares of fine residences between it and the beach. Land is gained there but lost at Chelsea, farther south, where the pavilion was moved inland twice on account of the encroachment of the ocean. Some building lots are now under water. Seaside resorts

Sea Caves at La Jolla, California.

along the coastal plain generally depend upon artesian wells for a water-supply. At Atlantic City there are two sources: wells 500 feet deep and water from Absecon. These wells tap deep strata that slant toward the ocean and carry the rain-water from far inland, where it has filtered down through sand.

There are several attractive sections of coast-line in California that deserve mention. La Jolla is but a few miles from the Mexican

line and a few miles south of San Diego. It has a most interesting and marvelous beach, on account of the sea caves and other curious forms of erosion. Caves along the shore-line are generally due to the fact that there are alternate layers of hard and soft strata; if the soft strata are exposed to the waves, they will be cut back, eroded, and caves will be hollowed out. These caverns extend back for about seventy feet, and at low tide they can be safely entered. There are a series of columns, and also aisles cut which connect the caves. The formation, as I recall it, is a soft, yellow sandstone, slightly colored with iron, and but slightly coherent—in fact, it is a formation of recent age, and disintegrates very readily. Horizontal layers are exposed to the waves in commanding bluffs perhaps a hundred feet high. Along the sides of these bluffs, far above the water's edge, are some curious effects of erosion—knobs, columns, and carvings—in this soft rock. From the tops of these high cliffs may be seen schools of fish strikingly resembling gold-fish. They are bright red, and are known as the tom-cod. Sea-anemones cluster by the hundreds to the rocks near shore, in the shallow water. Farther north, along the bay, is the beautiful harbor of San Diego, where Point Loma, a bold promontory, helps to inclose San Diego Bay. From San Diego north along the California coast, for a distance of seventy or eighty miles, is a series of low hills and narrow strips of sandy beach. These hills are brown and bare in the summer, when there is practically no rain and the grass becomes sun-cured. Near Los Angeles are Santa Monica and Redonda, two popular strips of beach, the Atlantic City and Cape May of California as regards popularity as seaside resorts.

Santa Monica is built on high bluffs of diatomaceous earth, which stand back from the ocean, leaving a narrow strip of coarse, sandy beach in front. This diatomaceous earth is a soft, easily eroded, recent formation. Fortunately, the bathing beach is some distance above the waves, because if this soft, diatomaceous rock were an exposed shore-line, it would suffer severely from wave action. Along the bluff are groves of palm and eucalyptus. It is curious there is so little bathing along the Pacific coast; the water is comfortably warm and the beach is fair, although not to be compared to the eastern beaches. You will see five and sometimes ten thousand people along the bathing beach at Atlantic City, N. J., on a hot summer day, but along the California beach it is a rare thing to see four or five hundred. It is

not so hot in California, and I suppose that is one reason. From near the bay of San Luis north along the coast to Monterey we have a coast-line about eighty miles long, which is rocky. The range known as the Santa Lucia slopes abruptly to the sea. This strip of coast is but little settled, as it is too rocky and there are no harbors. One of the prettiest strips of beach along the California coast is at Monterey, where Monterey Bay forms a small harbor. There the granite rocks

DIATOMACEOUS BLUFFS AT SANTA MONICA, CALIFORNIA.

come right down to the shore-line. At low tide you see sea-anemones by the hundreds—big fellows almost the size of one's hand; also many starfish cling to the rocks, where they are all exposed at low tide. Monterey was formerly the principal whaling town of the Pacific. Del Monte, the garden spot of California, which is located in a grove of 200 acres of tropic and subtropic trees, has often been described. The remainder of the coast-line of California north of San Francisco is mostly rugged, being hilly or mountainous. The Columbia

BEACH AT SANTA MONICA.

River, which forms the boundary between Oregon and Washington, affords a magnificent harbor. It drains the western slope of the Rocky Mountains, and is navigable all the way to Portland—a distance of 100 miles—for sea-going vessels. There is a dangerous bar at the mouth of the Columbia River, which is not so much dreaded as formerly. The Columbia is undoubtedly the great river of the Northwest. Those of you who have traveled through the Southwest, in California, Arizona, New Mexico, etc., have noticed the great difference between the rivers there and the rivers in the North. There are very few noble streams in the Southwest. We would not expect them in that arid district; streams that are there called rivers we would call creeks. Even the Colorado River, in the Southwest, although it is an enormous river, is very shallow, especially at the Needles and Yuma.

The coast-line of Alaska is broken, like that of Maine or Norway. The ocean extends inland as bays, submerged river valleys, or sounds, or as inlets known as fiords. The length of the coast-line, counting these indentations, is about eighteen thousand two hundred miles—longer than the coast-line of the United States on the Atlantic and Pacific. The hundreds of islands off the Alaska coast cover an area of 31,205 square miles, and they are mountainous. The view shown illustrates the character of the coast-line. You see what a great difference there is between these peaks and those along the coast of Maine and in the State of Pennsylvania. The Appalachian peaks are round and dome-shaped, and very old. They were at one time high mountains, and were worn down by erosion. These peaks along the shore of Alaska are very young as compared to the Appalachians or to the peaks in Maine; in fact, Mount St. Elias is one of the youngest mountains in North America. Pleistocene strata have been found along its slope; part of this mountain was uplifted during the occupancy of the earth by man. The youthfulness of these Alaskan peaks along the coast is shown by their sharp-pointed outline. They are heavily forested simply because they have an enormous rainfall—a rainfall of over one hundred and twenty inches per year, which is more than three times the rainfall in Pennsylvania. The warm, vapor-laden winds from the Japan current yield copious showers when their moisture is condensed in ascending the slopes.

DISCUSSION.

PROFESSOR CARTER (in answer to questions).—The rivers of the Appalachians, the Delaware, the Schuylkill, the Susquehanna, and Potomac,—in fact, nearly all of those rivers flowing in a southeasterly direction,—have cut gaps through the Appalachian Mountains. There is one river, however, which does not flow in a southeasterly direction across the Appalachians, but flows northwest—that is the New River, which is a branch really of a larger river, the Kanawha. According to recent investigations, this is explained as follows, although some geologists perhaps do not accept the view. In the old text-books one will find nothing about stream-capture; very little attention is given to water-gaps or wind-gaps; in fact, the study of rivers has been neglected. The explanation given by Professor Davis of Harvard, and others who are following up this line very closely, and to whom we are indebted for a great many facts that have been brought out, is that there was a time when these mountains (Appalachians) were worn down to what is known as a peneplain; and at that time all these rivers which I have mentioned, —the Delaware, Susquehanna, Potomac, and James,—instead of flowing southeast, as they do now, flowed in an opposite direction, northwest, because the plain was tilted in that direction; afterward, when the elevation began, the peneplain, so-called, was tilted in a direction toward the Atlantic Ocean, and the rivers began to flow toward the Atlantic Ocean, but they cut these channels before the mountains we now term the Appalachians were elevated. The New River is the only river remaining which retains the direction in which it formerly flowed.

I have not made an extended special study of this river question as yet. I am interested in it and at work on it now. The fact that these rivers once flowed in an opposite direction from which they do has only been pointed out recently, but there was a paper published at the Academy of Natural Sciences several years ago which antedated, you might say, these later investigations. I think that paper is not generally known. It was written to show that the Delaware River at one time flowed in an opposite direction from which it does now. If I remember correctly, the point brought out was that the Delaware flowed in an opposite direction, and now, according to investigation, not only the Delaware, but all the rivers of the Appalachians, flow in an opposite direction. The New River is the only one which retains its former course.

EDWIN F. SMITH.—How would you explain the fact that there are deposits of what appeared to be submarine shells at elevations in eastern Pennsylvania as high as 500 feet above the tide. There are deposits of that nature in the red shale and sandstone formation north of the Blue Mountains at Auburn, Penna., 475 feet above tide-water.

I have heard a theory that the South Mountain range at one time was higher than the Alleghenies; the former probably five thousand feet high, whilst the latter averaged about two thousand five hundred; and that through some convulsions of nature the South Mountain range was leveled off, and at about the same time the gaps in the Blue Mountains made their appearance at the Delaware Water Gap and at the Lehigh, the Schuylkill, and the Susquehanna Rivers. The whole course

of the Susquehanna River, from the gap in the South Mountain range above Columbia to tide-water, is filled with boulders and the debris of the rock formation of the country, indicating a violent convulsion of nature and the erosive action of water, to which you have referred.

There are indications which would seem to corroborate the theory that these rivers at one time, ages ago, flowed northward into the great inland sea, on the shores of which we may suppose were formed the deposits of shells to which I have referred.

How do you explain these deposits of shells? There is no generally accepted theory, as far as I know, and the whole subject is one of conjecture only.

PROFESSOR CARTER.—Unless I knew the character of the shells and age, I would not venture an explanation. We have deposits of gravel and sand in this neighborhood at considerable elevation above tide. We have gravels at Bryn Mawr, for example—400 feet above tide. There seems to be a difference of opinion about the age of these gravels. There are gravels at Three Tons, in Montgomery County, about four miles back of Ambler, and gravels in Chester Valley, resting on the limestone, over two hundred feet above tide.

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, September 16, 1899.—The President in the chair. Forty-eight members and eight visitors present.

The Secretary announced the death of Mr. Walter D. Heston, which occurred in Central America in the latter part of July.

The tellers reported the election of Messrs. A. Hale and J. P. Webster to active membership, and A. B. Stitzer to junior membership.

Mr. W. C. L. Eglin exhibited and described a portable electrical testing set arranged especially for testing underground cables.

The subject was discussed by Messrs. Scott, Hering, Manwaring, and Schumann.

REGULAR MEETING, October 7, 1899.—The first Vice-President in the chair. Twenty-eight members and two visitors present.

Information having been received that Professor Wm. H. Burr was unable to present the paper on "Long Span Bridges," the meeting adjourned without further business.

REGULAR MEETING, October 21, 1899.—The President in the chair. Fifty-six members and fourteen visitors present.

A topical discussion upon the subject "Philadelphia: What Are Its Needs?" was opened by Mr. H. V. B. Osbourn, and continued by Messrs. Souder, Schermerhorn, Christie, Morris, Wm. R. Webster, Marburg, Trautwine, and Schumann.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, September 16, 1899.—Present: The President, the Vice-Presidents, Directors Humphrey, Ott, Smith, Levis, and Souder, the Secretary, and the Treasurer.

The Treasurer's report showed balance, August 31, 1899, $1318.03.

The resignation of Mr. S. E. Fairchild, Jr., from the position of alternate teller was presented and accepted. Mr. R. G. Develin was appointed to fill the unexpired term of Mr. Fairchild.

REGULAR MEETING, October 21, 1899.—Present: The President, the Vice-Presidents, Directors Levis, Ott, Evans, Smith, and Humphrey, the Secretary, and the Treasurer

The Treasurer's report showed balance on hand, September 30, 1899, $1472.58.

The Library Committee reported a list of books donated to the Reference Library and of cash subscriptions for purchase of reference books.

The Publication Committee reported that suits had been entered against all delinquent advertisers, resulting in the collection of $132.50 at a total cost (attorney's fees and other charges) of $32.50.

ADDITIONS TO GENERAL LIBRARY.

FROM THE METROPOLITAN WATER BOARD, BOSTON.

Fourth Annual Report.

FROM THE U. S. GEOLOGICAL SURVEY.

Eighteenth Annual Report, 1896–7, Parts I, II, III, and IV.
Nineteenth Annual Report, Parts I, IV, and VI.
Astronomical Papers, VIII Part II
Monographs XXIX, XXXI, and XXXV.

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ERRATUM.

Page 284, for "*wrens*" read "*orens.*"

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LONG-SPAN BRIDGES.

WILLIAM H. BURR.

Read November 4, 1899.

IT was my intention that this paper should be prepared in a way commensurate to the importance of its subject, but, unfortunately,—for me at least,—the summer on which I had counted as the time during which such preparation could be made passed out of my control, so that I am not able to present the analytic part of the work. I shall at least endeavor to present some, perhaps crude, ideas relating to long-span bridge design, in the hope that possibly some one may be inclined to take up those portions of the subject which I have not been able to prepare for this evening. It is a very important subject for American bridge engineers at the present time, because we have come to that point in the engineering work of this country when bridges of unusual span must be constructed. We have two or three either already constructed or in process of construction. I refer to the old East river bridge, known as the Brooklyn bridge, and the new East river bridge. Both of these structures have spans which are certainly unusual, although they have been exceeded by the span of the Forth bridge.

In order to begin with the subject in a rational manner, it is necessary to consider some of the elementary features of ordinary bridge

design. The prominent type of American bridge is, of course, the simple non-continuous span, which is represented in its most elementary form by the plate-girder. The functions of the flanges and web of the girders are identical with those of the chords and web-members of the ordinary simple non-continuous truss. In the solid web of the plate-girder the condition of the stresses is a matter open to some difference of opinion. In fact, the stresses probably travel in different paths according to the presence or absence of stiffeners, but whatever may be the details of that stress condition, it is certain that we have stresses either more or less nearly vertical or inclined at various angles—that is, the metal of the web is so disposed, and must be so disposed, as to permit stresses to travel in a more or less zigzag manner between the flanges of the girder, precisely as in different types of web-members of trusses. Those web-members may be vertical or inclined, or all inclined, but the stresses travel in a more or less oblique direction from one chord to the other. In other words, there is considerable metal required between the flanges or chords to enable the shearing stresses to pass from one chord to another, and to give to those chords the stresses which exist in them. In these structures there is a large number of members with their various details, and they are so conditioned in reference to the moving load that the working stresses in them are comparatively low. In other words, those working stresses are comparatively small fractions of the ultimate resistance of the metal. That, perhaps, is something to which we are so accustomed in ordinary daily practice that we fail to give it much consideration. As a matter of fact, a working stress which is from one-fourth to one-fifth of the ultimate resistance is a low working stress. Again, the metal of such structures is what may be called of ordinary character. It is metal which has to be used in considerable masses and which must be produced at the lowest possible unit cost. In the ordinary, simple, non-continuous bridge it is sometimes difficult to design members which are massive enough—that is, if they are designed to meet the actual stresses which exist their sections are too small for such stiffness and stability as is desired in a first-class bridge design. Under these circumstances it is a matter, perhaps, of relatively little consequence in what shape the metal is used or in what manner the stresses travel—to use that expression for lack of a better one—from the points of application of loading to the points of sup-

port or the points of reaction. In existing long-span simple truss bridges, of which we have a considerable number of excellent examples in this country in which the spans are from 500 to 550 or more feet in length, there is shown, I think, excellent engineering skill in the disposition of the metal to meet the conditions under which it is used.

There are various resources of design by which multiple systems of bracing are eliminated, resulting in relatively large sections of metal concentrated in a few members; and whatever may be said about the stiffness of multiple systems of bracing connected at intersections, I think that what may be called the massive design of few members in our long-span bridges is a very excellent feature. It is not my purpose to make any observation in this connection which even would appear to be a criticism of multiple systems of bracing with riveted joints; but I think there is little difference of opinion, among American engineers at least, as to the best of the very long-span bridges now built being excellent examples of bridge design, and I believe, with scarcely an exception they are designed with single systems of bracing. It is not my judgment that the single system long-span design, as found at the present time, has reached its limit of applicability, by any means. It would not be surprising to find spans within a few years reaching eight hundred feet or more in length, but in view of the working stresses which it is feasible to use and with the metal which must be employed in such designs, I can see no reason at the present time to believe that that system of design can possibly be adapted to the great spans of from fifteen hundred to three thousand feet, which may be attained within a comparatively short time. I am speaking, obviously, from a point of view of such metal as we now have and can foresee in that part of the future which is within the reach of our observation.

All these non-continuous spans or other ordinary truss-bridge designs are, so to speak, self-contained. Their reactions are vertical, and there is no part of the structure outside of the immediate limits of the span; but it is a question, and a very serious question, whether that is the proper type of bridge for the longest spans which must be constructed in the future. It has been customary in the past to consider the cantalever as a type of structure which is well adapted to great lengths of spans, and to a certain extent that is true, but there

is in the cantalever one serious defect. It is precisely that which we find in the simple noncontinuous span, and to which I have already adverted. There is altogether too much path to be traversed by the stresses. The cantalever is nothing more or less than the ordinary bridge truss made continuous over the piers and reaching back outside of the limits of the span to such distances as may be found advisable. We have the same chasing of stresses, so to speak, from one chord to the other, that is found in the ordinary truss bridge. In other words, the paths of stress from the points of application of the loading to the points of reaction are excessively long. There is that zigzagging across from one chord to the other and, consequently, the placing of metal along these lines which we have in the ordinary truss and which is fatal to economy in all long spans. In addition to that, the cantalever possesses other economic disadvantages. Its reactions are both upward and downward, and that condition, together with the corresponding truss continuity, brings excessively heavy shearing stresses on web-members. It is fairly well adapted, however, to the lower lengths of long spans; and it is absolutely necessary if the truss form of construction is to be used where false works can not be employed. The Forth bridge is the most marked instance of cantalever construction that has been completed, although it is not a design which would ever be imitated. Its proportions are very injudiciously taken, and there is failure to reach the degree of economy which ought to exist even in the cantalever.

In all the structures so far considered the compression member in the form of a long column plays a very important part. In fact, it predominates to such an extent that more than one-half of the weight of metal in the trusses is found in that form. That in itself, at first sight, might not appear to be very serious, but, as a matter of fact, it is a very serious feature of design. It involves the material reduction of working stress which must go with every long column, necessitating a much increased section over a tension member carrying the same load. One of the first steps in the development of the long-span bridge design must be such as will enable the metal to be used so as to give a high working stress together with very direct paths for the stresses from points of application of loading to the points of support. That may require a part of the structure to be outside of the limits of the span, which may appear disadvantageous. If those parts

which are outside of the limits of the span are small, and can be made in such a way as to waste little material on details and be used with a high working stress, the economy will be very apparent—at least after a little consideration. Obviously, the simple tension member long enough to reach from one limit of the span to the other is a very economic member in itself if it can be made to do the work of the structure. It is obvious, also, that a compression member can not be made to occupy such a condition simply because it does not tend to hold itself in position. It must be braced, if used in compression, precisely as in an ordinary truss. There are lengths of span under which compression members, as principal members, may be used to advantage; but I am now speaking of the longest long-span bridges. The type of structure which meets the fundamental requirements which have been set forth in this rather elementary and crude manner is the stiffened suspension bridge. That structure has as its principal carrying feature a simple tension member stretched from one limit of the span to the other in a nearly vertical curve, and held at the tops of the towers by the backstays. The metal used in the cables may be such as to admit of the highest working stresses known to structural engineering practice. The ultimate resistance of wire suitable for cables is very high: certainly not less than 180,000 per square inch at the present time, and it could probably be increased a third beyond that value with no sensible increase of cost. The main members of the structure are exceedingly simple, and so placed as to carry the stress in almost the shortest possible path that can be conceived of.

Since very high working stresses can be used, and since there are few main members of the structure, it is obvious that such a design would be utterly unfit for short spans. We should have members too light and flexible, and given to too much vibration; hence, they would be ill calculated to take moving loads. Under the circumstances of shorter spans than those which are required for the longest crossings, we may use what is practically a stiffened suspension bridge turned over;—*i. e.*, with the cable displaced by a compression member;—in other words, by the arched rib, which, in my opinion, is a form of structure that will be very much employed in the future. The arched rib is not adapted to every short crossing but for many crossings where the long-span feature is desirable, and where the condi-

CANTALEVER AND TRUSSED ARCH ACROSS NIAGARA GORGE.

CANTALEVER BRIDGE, MEMPHIS, TENN.

tions are such as to require a graceful, and at the same time stiff, bridge, it is an excellent structure. As a matter of fact, a stiffened suspension bridge and a stiffened arch are so nearly alike that precisely the same analysis will answer for both—that is, one may establish general formulæ for the computation of stresses in the main members of the stiffened arch, and apply them directly to the stiffened suspension bridge, or vice versâ. A general analysis of the type of stiffened structures will give a system of equations which may be developed for special features in each of the two cases; but, so far as the main equations are concerned, they are the same for both. In each the stresses in general are carried very directly from the points of application of loading to the reactions. The only modification of that observation (and it is a partial modification only) lies in its application to the metal which is required to hold the curved members (whether in tension or compression) in their proper alinement under the action of the moving loads.

I shall call your attention only to some diagrams of skeleton stiffened suspension bridges; although in each case we can turn them over, subjecting the main members to compression and thus have the stiffened arch. At the present time there has not been a sufficient number of designs of stiffened suspension bridges made to determine just what method of stiffening is the best for every given span; yet, in developing the stiffened suspension bridge it is necessary to take into consideration in just what manner the stiffening metal shall be placed. Certain stiffened suspension bridges have been built of what one may call the modern type, but not of long span. The old Brooklyn bridge and the new East river suspension bridge are examples of what we may call the older type of suspension-bridge construction. In those bridges the stiffening metal is placed in a stiffening truss, along the lower chord of which the moving load is carried. That illustrates the general type of stiffened suspension bridge in which the shape of the cable is maintained by an entirely independent member —the stiffening truss. The scale-sketch shows the general type of such structures, although the joint at the center is absent from the stiffening trusses of both the Brooklyn bridges. The stiffening truss which is used in connection with such structures may be continuous from end to end of the span, and be anchored down at each end, but in such a way as to permit horizontal movement at those ends, or it may

be anchored down in precisely the same manner and be jointed at the center, as shown; or, again (what, in some ways, is a decided improvement), the joint at the center may be omitted and the stiffening trusses made continuous and carried back of the towers to be anchored down at their extremities. I think no such structure has been built; but such trusses have been designed. In that case there would be a point of support to the stiffening truss at the tower at each end. There would be rocking struts, extending down to such elevations as may be best suited to accomplish their purposes at both the towers and at the ends of the trusses, to serve as points of anchorage and of support. This type of stiffening truss has some advantages.

The type which is illustrated by the Brooklyn bridges and by the diagram is the oldest; in it the cable is used simply to sustain the dead load of the structures and the moving or live load. The entire stiffening effect—that is, the distribution of the moving load (whatever may be its location) in such a way as to stress the cable in its constant and normal position—is a straight member. The backstays may be carried in a straight line if they are supported, or they may be allowed to take their natural curve. Obviously, if the cable can be made economically to hold its position under a traveling load, there will result the conditions for an extremely economic structure.

It is always assumed that the curve of the cable is parabolic; but if the live load covers any portion of the span, the tendency is to deflect the cable in that portion and to raise it in the other part of the span. Inasmuch as the parabolic curve necessitates a uniform distribution over a straight line of all the vertical loading, it is clear that the stiffening truss must act in such a way (no matter what portion of the span is loaded) that all the suspenders from one end of the span to the other will be stressed uniformly. This is, probably, seldom exactly true in any case; but it may be so nearly true that the disturbance of the cable is too small to be of any material consideration.

The old theory of the stiffening truss was such as to obviate the use of any equations which involved the elastic properties of the material. It virtually assumed that all the suspension rods and the cables were rigid, incapable of extension, and that the stiffening trusses themselves were without deflection under any condition of loading, making the problem one of pure statics. The fundamental equations of conditions from which the bending moment and the shears were

computed, and by the aid of which all members were designed, thus involved in no way whatever equations of elasticity.

The modern system of stiffened suspension-bridge design is somewhat more advanced. It is of such a character that the stretch of the suspension rods, the stretch of the cables, the deflection of the stiffening trusses, and even the compression of the towers, if desired, are taken into consideration. The constant, horizontal component of stress in the cable is, or may be determined on the condition that the total work of elastic distortion of all those members shall be the least possible. The equation or condition of least work, as it is called, is, so to speak, the elastic supplement to the ordinary equations of static equilibrium, necessary for a sufficient number of equations to determine all the unknown quantities of stress computation. It is not a theory which involves any great amount of work, although it is a little more laborious than the old method. At any rate, the amount of labor involved is certainly small in view of the importance of securing as nearly accurate design as possible. Wherever a substantial advance in engineering design can be secured, the small additional labor of computation which is involved in making that advance is a very small price to pay for it. Every essential advance in structural design which has been made in this country during the past thirty years has largely involved just such advance in analysis as is required in passing from the old static theory of stiffening trusses to the more advanced and satisfactory one.

I have dwelt upon this matter a little more than perhaps may seem necessary, because it has been alleged in some quarters that even this theory is too loosely approximate to have any advantage over the old: that the suspension rods are of different lengths, and consequently that they are stretched differently; that the deflection of the truss will not be quite as is assumed in the equations of the theory; that it is a question how much the towers will be compressed and how much the masonry; and, after all, inasmuch as we can not reach a theory absolutely correct, there is little use in attempting such refinements at all. Such views, however, are in opposition to all progress. It is impossible to reach exact theory in any engineering work; but the ideal can be approached more and more, if we recognize the necessity and the advantage of doing it; and that is precisely what should be done in connection with this suspension-bridge theory. There is in the most advanced analysis a perfectly rational basis for at least recogniz-

TRUSSED ARCH ACROSS NIAGARA GORGE.

WASHINGTON BRIDGE (ARCHED RIBS) ACROSS HARLEM RIVER, NEW YORK.

ing the main features of the conditions which hold in the design of such structures; and it seems to me, as professional men who are in earnest in professional work, that those features should be recognized in the analysis employed.

The maxima bending-moments and shears in the stiffening truss for the new theory and the old are not very different, and the latter may well be used for approximate estimates. The chord stresses and shears in individual members may, however, be very different, and the new theory should be employed for final calculations. The greatest value of moments and shears in the two cases are as follows, very closely:

	p = load per lin. ft. *Old theory.*	*l = length of span in feet.* *New theory.*	
Max. moment, . . .	$M = 0.01856\ pl.^2$	$M = 0.01652\ pl.^2$	no center hinge.
Max. shear, ...	$S = \frac{1}{2}\ pl.$	$S = \frac{1}{2}\ pl.$	
With center hinge, .	$M = 0.01883\ pl.^2$ and	$S = \frac{1}{2}\ pl.$	

The skeleton structure here shown was a provisional design, made only for the purpose of comparative estimates between a cantalever and a stiffened suspension bridge each of 3100 feet span. That was the problem before the board of engineers which, over five years ago, considered the feasibility of spanning the Hudson river at New York city with a single span of a little over 3000 feet in the clear.

I have said that it was necessary to use elastic equations of equilibrium in connection with the design of the stiffening trusses for this type of stiffened suspension bridge. That is true if the truss is continuous from one end of the span to the other, as I think it advantageously may be; but if the stiffening truss is jointed at the center, there is introduced the additional condition that the bending-moment at that point shall always be zero, whatever may be the condition of loading. Such a feature gives one additional equation of condition which eliminates the necessity of using the elastic equation; hence, in the case of the stiffening truss jointed at the center, the simple problem of static equilibrium results, and all the equations necessary for the computations are equations of statics without any reference to the elastic qualities of the material. A center-hinged stiffening truss was used, as shown in the figure, by the board of engineers for the comparative estimates adverted to. There is little difference in economy between a continuous stiffening truss and one jointed at the center.

There are somewhat greater bending-moments in the latter case; but, on the other hand, they are bending-moments whose maximum prevails only at a point in each half-truss, making the average moment comparatively low; whereas, in the continuous stiffening truss, maximum bending-moments prevail over approximately one-third of the span. There is, however, one criticism that may be made as in all cases of pin-joints or hinges in the central portions of the structure: those joints decrease stiffness, although that is a matter of less relative consequence in long spans than in short ones.

The other principal methods of stiffening suspension-bridge cables are shown in figures 1, 2, and 3. (See Plate A.) We have in figure 2 a type of structure which has been used for the Tower bridge at London. The central opening is a bascule structure of 200 feet clear span. One-half of the stiffened span reaches to the top of the tower adjacent to the bascule span; but the other half reaches only to the top of a lower tower at the shore end of the span. Both the curves are parabolic, but they are not branches of the same parabola. The lower curve is one parabola nearly up to the span center, but another parabola completes the curve over the remainder of the span. The other curve crossing the first at the center is formed in precisely the same way, but with the portions of the span reversed. The center line is also a parabola of two equal branches—that is, it is a parabola of the same parameter for the entire span.

The object in placing two cables in that manner, with bracing between them, is to accommodate unsymmetric or partial loading. The most unbalanced loading is that which covers the whole of one half-span. In the figure one of the curves (upper in one half-span and lower in the other) represents the true position of a cable for such loading. The broken line curve, midway between the others, shows the parabola for a uniform load over the entire span. The true parabolic cable for any partial uniform loading whatever will always be found between the extreme positions above indicated. The bracing between the extreme positions of the cables, together with the cables themselves, constitutes the stiffening truss of this type of structure. If two tension members are placed in those extreme positions, so that the line of resistance for any portion of uniform loading whatever will lie between them, the only function which the bracing connecting the cables will have to perform is to transfer such small amounts of

shear as may be required to make the proper distribution of tensile stress between the cables. Whenever a uniform load covers the entire span, the bracing will have no duty to perform except simply to keep the tension members separated at their proper distances. That is a form of stiffened suspension bridge (a stiffened arch, when it is turned over) which has been advocated by the English engineer, Max Amende. It has many advantages. In fact, I am not sure that it may not be the most economic system of stiffening for the longest spans. The roadway, or the railroad platform, would be stiffly suspended from the stiffening truss; but simply deep enough and stiff enough in itself to take the shocks, irregular applications, impacts, or vibrations of any rapidly moving load. It would have no function as a stiffening truss. The entire stiffening-truss function, so to speak, would be performed by the two tension members and the bracing between. It is obvious, I think, that under these circumstances this bracing may be relatively light, and that the two tension members are in position to carry the stresses very directly from the point of application of the load (wherever that may be) to the tops of the towers and the anchorage. It is not only a very economic type of stiffened suspension bridge, but when it is turned over so as to make a stiffened arch, it is a very economic form for such a structure.

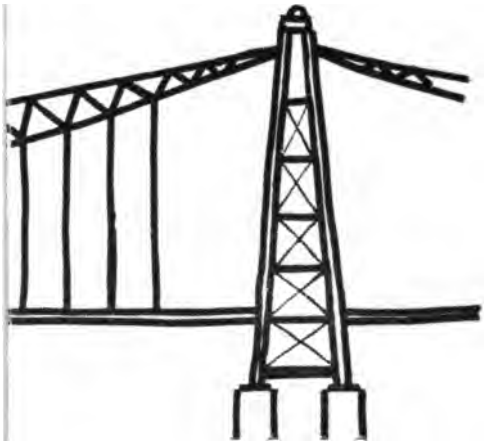
Figure 1 exhibits another example of the same general type. The stiffening members are entirely above the cable, but connected with it. The cable forms a part of the stiffening truss, as it did in the preceding instance. The curve of the tension member along the lower limit of the bracing is a true parabola, symmetric about a center line. Straight lines are then run from the tops of the towers to the lowest point at the center. The Point bridge at Pittsburg belongs to this type of structure. If the load is placed at the center, the two straight tension members carry it; if it is uniformly distributed from end to end, the parabolic cable is in position to take it without the aid of the bracing; and if the load is eccentric (over one-half the span, for instance), then the straight members act as the top chords of the stiffening trusses. The cable forms the lower chords of the stiffening trusses as they are needed, while the bracing carries such shears as may be required to be transferred between the straight chord members and the parabola. It is a very economic form of stiffening truss, although

JEFFERSON AVENUE (STIFFENED SUSPENSION) BRIDGE, ST. LOUIS, MO.

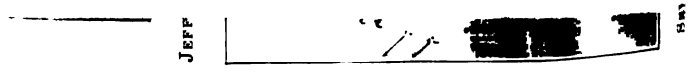
BUDA-PESTH SUSPENSION BRIDGE.

SEVENTH AVENUE (STIFFENED SUSPENSION) BRIDGE, PITTSBURG, PA.

PROPOSED STIFFENED SUSPENSION BRIDGE ACROSS HUDSON RIVER AT NEW YORK.



a good deal of serious attention, and I have little doubt that cables


JEFF

I doubt very much whether it may be economically applied to such short spans as the Point bridge.

Figure 3 represents a bridge with two concentric cables and with the bracing between them. The two cables are parabolic, and are capable of carrying any uniform load; while the bracing is so placed as to transfer shear from one to the other in case of an eccentric or unsymmetric loading. That is the form of stiffening truss which has been employed by Mr. Lindenthal in his design for the North river suspension bridge, with which it is proposed to cross the North river from Twenty-second Street to the New Jersey shore, in one span of about 3000 feet. That type of suspension bridge has been used already by Mr. Lindenthal at St. Louis and at Pittsburg. It has also been employed in Europe. It has not yet been employed for any very long spans.

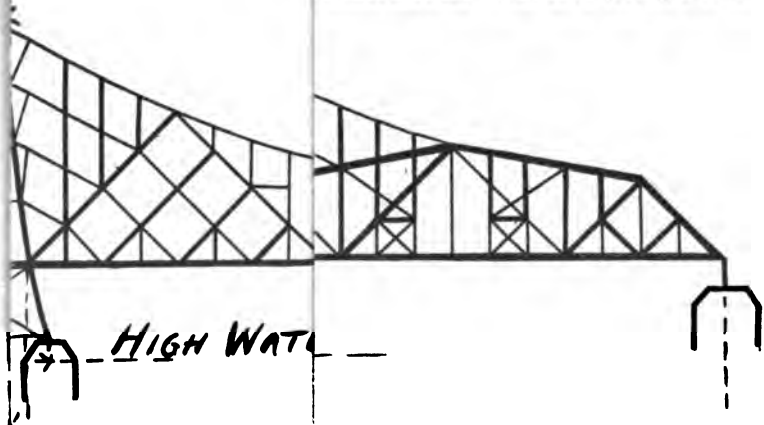
There are certain difficulties which attend these designs, but they are neither insurmountable nor inconsistent with a high degree of economy. They arise from stresses produced by changes in temperature or by elastic stretching of the cables. Variations in temperature in the cables of a suspension bridge cause very considerable deflections, but as they occur in long spans, they do not sensibly affect the passage of traffic. The total movement at New York city of the lowest part of a cable for a 3100-foot span may be as much as seven feet. As half that amount is the change of grade for half the span,—*i. e.*, 1650 feet,—it is seen that the deflection is not of material moment. What is more serious in the cases of the stiffening members being placed along the cables is the temperature stresses which are developed in those members themselves in all types of that class. They are not, however, beyond computation to a reasonable degree of accuracy, and need not be considered as any serious difficulty in the way of designing satisfactory structures. They have been computed in a number of cases, and while they exist to a considerable magnitude, they are not too great to be provided for with economic sections.

In order that any type of suspension bridge may be made practicable, it is desirable, I think, that some other method of forming the cables should be devised than that of slowly weaving them, so to speak, as has been done in all cases of wire cables to the present time. The matter of an improved method of laying the cables has received a good deal of serious attention, and I have little doubt that cables

may be designed to be laid with all the accuracy that is required for such structures, in possibly one-third of the time that has been required in the old manner of construction. It is, perhaps, a little hazardous to express such an opinion without supporting it by explicit statements of methods of procedure, but enough has been done, I believe, to point to such results with certainty. At any rate, while we have seen what are really marvelous advances not only in the designing of ordinary truss bridges, but in their methods of erection, we have seen practically no progress in the design and erection of suspension bridges of considerable span in this country. That is a condition which has resulted from the fact that few suspension bridges have been built. There has been no such demand for them as for the ordinary truss bridge, and hence no such stimulation of devices and fertility of resource as have been developed in connection with ordinary bridge construction.

In the new theory of computations it is seen, as would be expected, but as it is not seen in the old theory, that the deeper the continuous stiffening truss is made, the more of the moving load the stiffening truss carries as a truss, and the less duty the cable performs. The chief purpose, obviously, is to throw as much carrying duty on the cable, with as little on the truss, as possible. Consequently, the depth of a stiffening truss, not jointed at the center of the span, should be made just as little as is practicable to accomplish the purpose of such a truss. In other words, there must be depth enough to afford the requisite stiffness to keep the cable in its proper position, but no more; otherwise, a greater portion of the load is thrown on the stiffening truss, to be carried by it as a truss, which should be avoided. The proper depth of truss in terms of the span should probably be not far from $\frac{1}{40}$ to $\frac{1}{45}$ of the span.

Probably the design of the cantalever was carried to as great a degree of excellence in the case of the proposed Hudson river structure as any yet reached (Plate B). The total length of clear span in this case was about 2000 feet. It was proposed to put one pier in the Hudson river a thousand feet from the New Jersey side. The total weight of metal in that case was about 300,000,000 pounds. When this span was increased to 3000 feet, the weight was increased to nearly 700,000,000 pounds,—*i. e.*, two and three-fourths times its original value. It is seen, therefore, that while it is feasible to con-


HIGH WATE
12 panels of 60'
OF END PINS
4120'

struct a cantalever bridge of the length of span of 3000 feet, it is not nearly so economic as the stiffened suspension bridge. The total weight of metal in the suspension-bridge span of the same length, including the towers, chains, and anchor-plates, was about 300,000,000 pounds. Adding enough viaduct structure on each end to make the total length equal the total cantalever length, the weight of metal in the stiffened suspension system was materially less than half that in the same length of cantalever structure, and the probability is that under a more mature design the difference would have been greater in favor of the suspension-bridge system.

There is greater stiffness—*i. e.*, less deflection for a given span—in the cantalever than in the stiffened suspension system, although the deflection of the latter is not serious. It is an open question just how far the simple, non-continuous span may be used with economy in competition with the cantalever; or, again, at what length of span the cantalever ceases to be as economic as the stiffened suspension-bridge system. The latter limit may be somewhere in the vicinity of 1400 to 1600 feet for highway spans, and possibly 2000 feet for railroad spans.

DISCUSSION.

JAMES CHRISTIE.—When structures of such magnitude as those alluded to are under consideration, the massing of material at joints and intersections frequently presents difficult problems.

A given design may be rational and logical in its general features, but less satisfactory when the details are considered. The local or secondary stresses may become of more vital importance than the primary or fundamental stresses. Viewing such a structure as the Forth bridge, in which immense tubular members intersect, and remembering the magnitude of the stresses represented by these members, one may readily have serious misgivings as to the uniform transference of the forces throughout the mass of material at the intersections. We know that a screw-bolt may be of such excessive diameter that the exterior may be severed before the interior is overstrained. The remedy, when it can be practically applied, is to use several bolts of less diameter instead of the single large bolt. In the same way it may sometimes be preferable to avoid the massive members, with the resulting unwieldy joints, by using multiple trusses, each of which is susceptible of comparatively exact determinations in the details of their joints and intersections.

JOHN STERLING DEANS.—It may be of interest to the members to know that the Phœnix Bridge Company recently had occasion to compare the relative cost of cantalever spans with suspension bridges, and found the economic length of cantalever spans extended to at least 1800 feet. This is with our present knowl-

edge and experience of the cost of suspension bridges. The length may be somewhat reduced as we build more suspension bridges, but up to this time the economic length of the cantalever bridges extends beyond 1800 feet. These computations were made by our designing engineer, a very careful and competent man.

COMMUNICATED DISCUSSION.

EDGAR MARBURG.—Engineers are doubtless agreed that for very long spans the suspension bridge is the only economically practicable form of structure. In the valuable report, made five years ago, by the Board of Engineers upon the proposed Hudson river bridge at New York—of which board Professor Burr was a member—comparative estimates indicated (*a*) that the cost of a 3100-foot, clear-span, cantalever bridge was almost double that of one having a 2000-foot clear span; and (*b*) that the cost of a 3100-foot, clear-span, suspension bridge was less than one-third greater than that of the 2000-foot cantalever bridge. The total length of the two structures was equalized by the assumed addition of viaduct approaches included in the estimates. While the above comparison is inclusive of substructure, the differences of cost are due almost wholly to the estimated differences in the cost of the superstructure.

With regard to the relative cost and relative merits generally of different types of suspension bridges for very long spans, very little definite knowledge is as yet available. Broadly speaking, the choice will have to be made between two general classes of designs: On the one hand, those in which the stresses are fairly determinate statically; and, on the other, those in which the stresses are essentially indeterminate without recourse to equations of elasticity. It is to be hoped that American engineers will eventually declare in favor of the former, unless the marked superiority of the latter in point of rigidity (not cost) can be convincingly established. With increasing spans the relative influence of the live stresses on the deflection decreases rapidly, and the tendency to produce vibration is minimized by the great inertia of the mass. Certain features of design, which have a legitimate place in shorter spans, but which render the distribution of the stresses more uncertain, may be therefore consistently avoided. The omission of the inclined stays in recent designs is a hopeful indication of a trend in that direction. In the absence of such stays the accident which recently befell the Brooklyn bridge, under an unusual combination of temperature conditions and loading, could not have taken place.

As pointed out by Professor Burr, the evolution of modern bridge design to its present high degree of perfection has not been brought about in a haphazard or empiric fashion, but has proceeded along strictly rational lines. At the same time it is a somewhat remarkable and, in some respects, a somewhat discouraging fact that the introduction of more refined methods of analysis and more scientific methods of designing have not been attended by a commensurate increase in the allowed working stresses. The average so-called safety-factor is probably as high to-day as it was twenty years ago. Nor can we flatter ourselves that it represents merely a reasonable safety-margin against contingencies; deterioration from exposure and service; and future increase of loading. On the contrary, it

stands chiefly as an implicit recognition of the fact that the accuracy of the computed stresses in modern bridge practice is largely fictitious. This is true in a marked degree of the live stresses from engine and train loading, even in the case of non-continuous trusses in which temperature stresses produce no sensible disturbances. In the case of swing bridges it may reasonably be assumed that differences of 25, 50, or 100 per cent. may exist at times between the computed and the actual stresses, especially for the smaller web-members. For this particular class of structure the added labor entailed by the new method of computation, compared with that in which the moment of inertia is assumed as constant, may be regarded as a sheer waste of energy. In ordinary cases, the differences in individual stresses by these two methods do not exceed 5 or 6 per cent., with the certainty that these irregularities will be completely overshadowed in the actual structure by stress disturbances from causes beyond the reach of computation. Moreover, these influences are of so erratic a nature that there is little or no assurance that the stresses resulting by the more laborious process are in reality nearer the true values than are the others.

In the case of suspension bridges there are, doubtless, certain types for which recourse must be had to the new method of computation in order that the stresses may be determined to a reasonably close degree of approximation, although I have not had occasion to make comparative computations by the two methods. However, in no class of structures is there greater need of resorting to all possible expedients tending to bring about greater determinateness of stress, provided that this may prove feasible without undue sacrifice of rigidity. An excellent precedent was established in Mr. Gayler's design of the Grand Avenue suspension bridge at St. Louis, in which the trussed eye-bar cables were united at a single pin-joint in the center, thus rendering all stresses statically determinate, the truss becoming simply an inverted three-hinged arch.

In a paper read before the club some years ago [1] I stated that, for railway purposes, the cantalever type of bridge seemed destined to occupy a field intermediate between that held by the simple truss for moderate spans—to about 600 feet—and that which would probably be covered by some form of suspension system, for spans exceeding 1500 to 2000 feet. While such figures, unless based on actual comparative designs under given conditions, can be regarded, at best, only as loosely approximate, it is seen that they agree substantially with those suggested by Professor Burr.

The economic advantages of cantalever bridges compared with non-continuous ones for long spans, are due chiefly to the fact that their economic mean-depth is considerably less. With a favorable length-ratio for the suspended span, the average bending moment in the central span (cantalever arms and suspended span) is only about one-third of that in a simple truss of the same length, while the shears are essentially equal. It is, therefore, practicable to adopt a considerably smaller ratio of width (between trusses) to span, than for non-continuous trusses. In the case of high piers, the usual accompaniments of long spans, this results in a great saving in masonry, besides the reduction in the weight of the floor-system.

[1] *Proceedings*, **13** (1896), 81.

THE ATBARA RIVER BRIDGE.

RICHARD KHUEN, JR.

Read November 18, 1899.

Probably every one here this evening has heard more or less about the bridge over the Atbara river, in the Egyptian Sudan, recently completed by the Pencoyd Iron Works; in fact, the words Atbara and Pencoyd have become almost synonymous. Many of you, however, have never seen a detailed description of this rather light, narrow-gage railway bridge, and have probably pictured in your mind's eye some immense structure like the Firth of Forth or the Brooklyn bridge. The amount of attention given to this work by the general public would naturally lead to this conclusion. This attention was, however, due to causes other than the magnitude of the work itself, the most prominent of which were (1) that the structure was urgently required for British military operations; (2) that the contract was given to an American firm by the British Government on account of the promise of much shorter delivery and lower price than could be obtained in England; and (3) that the work was successfully completed well within the contract time, in spite of unexpected obstacles. In other words, this enterprise gave notice to the civilized world that America is able to compete successfully with England in delivery and price for contracts given out even by the British Colonial Government.

Before entering upon a description of the engineering features of the bridge, I will give a short history of the events which led to its construction, and of the preliminary negotiations of the British Government in trying to place the contract.

General Kitchener's successful campaign last year against the Dervishes in the Sudan, the defeat of the Khalifa at Omdurman, and the consequent capture of Khartoum are, of course, familiar to every one. His success was made possible only by his excellent transportation facilities, comprising a continuous rail and water route from Cairo to Berber, a distance of over 1100 miles up the Nile. Berber is

just north of the junction of the Atbara river with the Nile; Khartoum is about 180 miles further south. A considerable portion of this line of railroad was built by Kitchener as part of his plan of campaign—namely, the line from Wady Halfa to Berber, about 350 miles across the Nubian Desert. From Wady Halfa to Assuan, the Nile forms a link between this line and the old railway

ATBARA RIVER BRIDGE, SUDAN, EGYPT.
(Built by the Pencoyd Iron Works, 1899.)

between Assuan and Cairo. The Nile could not be used further south than Wady Halfa, on account of the cataracts and rapids between it and Berber.

In order to continue his campaign against the Dervishes this fall Kitchener found it necessary to complete the railway line as far south as Khartoum. This necessitated bridging the Atbara river, which

is, at the bridge-site, about 1100 feet wide. During part of the year it is entirely dry, and the bed of the stream is used for camping grounds by the wandering tribes; but during the summer months, beginning the latter part of June, it becomes a raging torrent.

During the early days of Kitchener's campaign last year his engineering corps, having built the railway some distance south of the Atbara River, took up the matter of bridging this stream in order to carry his line of transportation nearer the scene of action around Omdurman, but found it beyond their power to do this themselves, on account of the rapid current. The project was, therefore, abandoned until after the fall of Khartoum in the autumn. It then became an absolute necessity, and, therefore, outside help was requested.

In response to the call for aid, the British Egyptian Government made inquiries in England early in October concerning this piece of construction. A promise of one year for shop-work and one year for erection was all that could be obtained. The reason given by the British manufacturers for this very slow work was the overcrowded condition of their shops. Second tenders were then asked of two American and five British firms, speedy delivery being the main consideration.

This table gives the names of firms, prices, and time of delivery promised:

			Delivered in	
United States.	*Liverpool.*	*New York.*	*Liverpool.*	*New York.*
Maryland Steel Co., . . .	2.55 cts.	2.30 cts.	4 months.	3½ months.
Union Bridge Co., ...	2.95 "	2.66 "	3¼ "	2½ "
England.				
Horsley, ...	2.89 "		3¼ "	
Head, Wright and Co., . .	3.00 "		6–9 "	
Joseph Westwood, ...	3.22 "		4¼ "	
	3.05 "		6¼ "	
Patent Shaft and Axle Co.,	3.42 "		5½ "	First span in 2 months.
Thames Iron Co., ...	3.45 "		5–6 "	

These tenders, together with plans, reached Egypt the latter part of December, 1898. It was then found that, since the bidders contemplated the use of falsework for erection in their designs, the work of erection could not be prosecuted until after the summer floods, and

could, therefore, not be completed until the following winter or spring, which would mean the loss of a year to General Kitchener. Accordingly, new bids, based on cantalever erection or launching, were asked for from all the firms already mentioned, to which was added the Pencoyd Iron Works. The following bids were received, the Patent Shaft and Axle Company being the only British firm responding to the final call:

Patent Shaft and Axle Co.,	3.37 cts.	per	pound	First span delivered in Liverpool in 2 months, and the rest each in 3 weeks (total 6 months).
Maryland Steel Co., . . .	2.3	"	"	3½ months in New York.
Union Bridge Co., ...	2.79	"	"	65 days in New York.
Pencoyd Iron Works, . . .	2.5	"	"	42 days in New York.

The Pencoyd Iron Works, allowing two weeks for shipment to Liverpool, promised the delivery of the work in one-third of the time asked for by the British firm and at a much lower price per pound. However, the price per pound of the Maryland Steel Company was slightly lower, but the time was more than twice that of the Pencoyd Iron Works.

The latter was, of course, accepted; but the British Government was very skeptical and intimated that the delivery of two or three spans in that time would be satisfactory. The Pencoyd Iron Works, however, adhered to the original promise of delivery, as it was much better for the shop to carry through the entire contract at one time.

I will now take up the description of the engineering features of the contract. The structure is a single-track, narrow-gage railway bridge, composed of seven pin-connected through spans each 147′0″ c.c. end-piers. The width c.c. trusses is 16′2″ and the depth 21′6″ c.c. chords. The trusses are of the ordinary Pratt type, with inclined end-post and stiff bottom chords and rest on steel cylinder piers 8′3″ in diameter, surmounted by cast-iron caps. The entire superstructure, including the cast-iron pier-caps, was designed with a view to erection without false work.

The substructure was built by a Cairo firm, which was the only one having facilities in Egypt for the quick prosecution of that part of the work. The Pencoyd Iron Works designed and furnished for New York delivery the entire superstructure under a lump-sum contract, the

cast-iron pier-caps and the erection plant and tools under a special pound-price contract. They also furnished the expert erection force, composed of a superintendent, two foremen, and five men (riveters, riggers, etc.)—the latter under a special agreement with the British government. The Pencoyd Iron Works were also held responsible for complete and proper erection.

The bridge was designed to carry two engines, each weighing 181,000 pounds, followed by a uniform load of 2240 pounds, or one gross ton. A unit stress of nine gross tons, or 20,200 pounds per square inch, was allowed on d + l + 50 per cent. impact, the dead load never to be taken as less than half the live load; also nine gross tons on all erection stresses. The material specified was medium O. H. steel, ranging from twenty-seven to thirty-one gross tons, or 60,000 to 70,000 pounds ultimate strength. The workmanship was made to conform to standard American practice, subject to the inspection of Messrs. Booth, Garrett, and Blair, of Philadelphia, who also made the customary tests on the material and on the full-sized eye-bars.

The one feature of the design which required more than the usual amount of attention was the method of erection without false work. This entire method was conceived and carefully worked out in detail in the engineers' office of the B. and C. department at Pencoyd, under the supervision of Messrs. C. C. Schnider, chief engineer, and Paul L. Wolfel, assistant chief engineer. Printed instructions, together with detailed plans, were issued to the superintendent of erection just prior to the departure of the erection force.

In plate 1 the upper sketch is a skeleton outline of the completed structure. The two lower sketches indicate the general method of erection, which was carried out as follows: One span, with about 60,000 pounds of steel rails on the far end, was erected temporarily on shore to serve as an anchorage for the first river span; a steel traveling derrick was erected on the top chords of this span, and a temporary connection between the two spans to take the horizontal tension in the top chords and the compression in the bottom chords was then made. The connection beween the top chords was made stiff enough to carry the traveler over the pier. After the connection over the pier had been made, the erection proceeded in the customary manner for cantalever bridges. As soon as the span was completed far enough to enable the booms to reach the next pier, the cast-iron pier-caps

II
III
IX
147'-0"
147'-0"
147'-0"
3
7
8

IDGE. Stress Sheet.
ection
2 Engines
as per diagram
2240# p lin ft
8'-9½"
4'-7½"
6'-11"
4'-7½"

were set. The span was then completed—*i. e.*, ready to be self-sustaining.

Provision had been made for keeping the far end of the cantalevered span clear of the pier by shortening the temporary connection between the top chords of the anchor and cantalever spans. When the cantalevered span was completed, the far end of it was raised by means of jacks,—as will be shown later,—so that sufficient slack was provided to remove the temporary tie between the two spans. This connection was removed with the rear boom of the traveler, and the far end of the span was lowered to the pier. The anchor span was then taken down and the erection of the next span carried out in like manner.

This general description is only intended to give a brief outline of the erection scheme, the details of which will be given later.

Stress Sheet (see plate 2).—The stresses from the engine load and the dead load were figured as usual for railway bridges, and then the erection stresses were obtained with the traveler in the extreme position. In proportioning the bridge, this combination of stresses necessitated (1) stiff bottom chords in place of eye-bars to take the erection compression; (2) heavy top chord splices to take tension; (3) a temporary continuation of the top and bottom chords between the spans and heavier diagonals and counters than would have been needed if the erection stresses had not entered into the design. After the bridge had been proportioned, the deflection of the far end under maximum erection stresses was figured. This deflection would be due to the combined upward deflection of the anchor span and the downward deflection of the cantalevered span, and was found to be $12\frac{1}{2}''$; to this were added $7\frac{1}{2}''$, the deflection due to lengthening the top chords for camber, making a total deflection of $20''$. A clearance of $4\frac{1}{2}''$ was added to this, making a total distance of $24\frac{1}{2}''$ that the end of the cantalevered span would have to be raised to clear the pier $4\frac{1}{2}''$. This was done by shortening the temporary tie between the anchor and cantalever spans $3\frac{1}{2}''$—or $\frac{1}{7}$ of $24\frac{1}{2}''$, as the depth of the span is about $\frac{1}{7}$ of the length. I understand that this clearance was actually from $4''$ to $5''$ in each case, comparing very closely to the calculated clearance. The effect of a wind pressure of 30 pounds per square foot was also considered on the cantalevered span and on the temporary tie. The usual stiff lateral bracing in the plane of the two

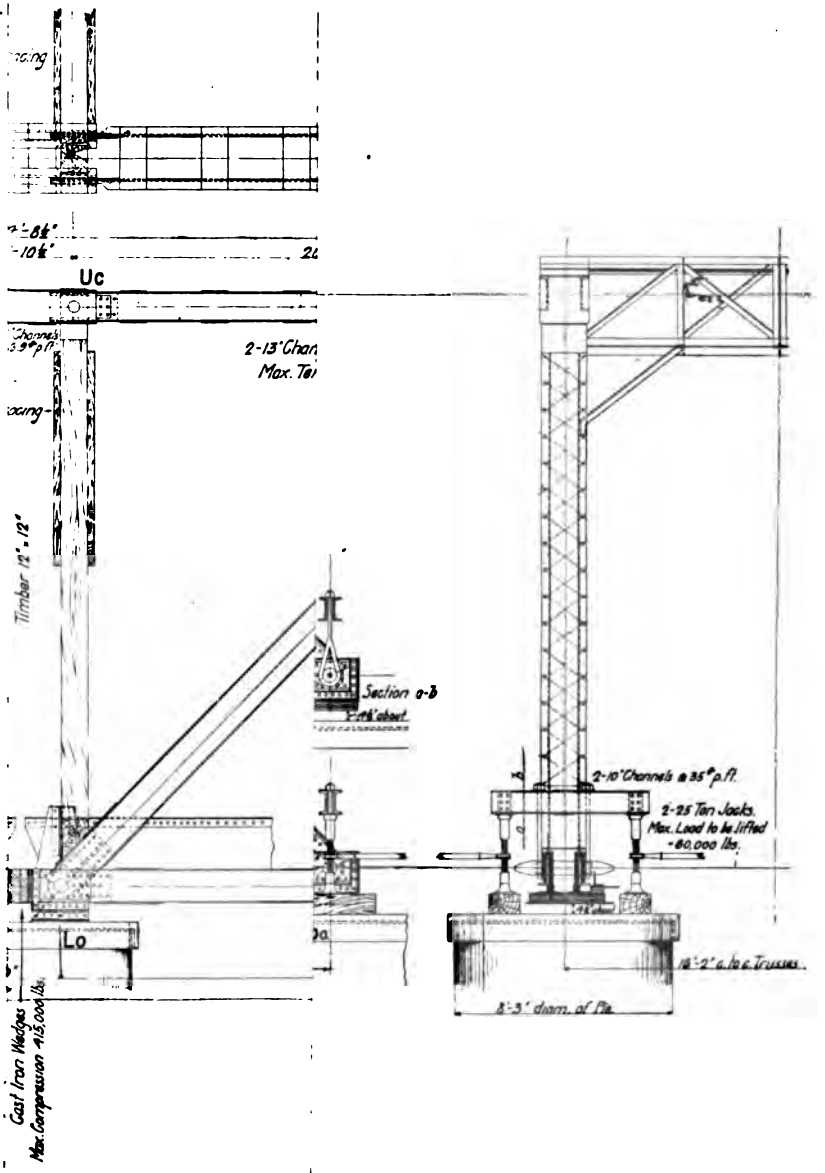
chords, the riveted portals and struts were found to be sufficient to take care of the resulting stresses, but the section of the temporary tie was increased somewhat.

General Drawing of Temporary Connection and Jacks.—Plate 3 shows the temporary connection between the chords of the two spans over the pier, and the arrangement used for raising and lowering the far end of the cantalevered span. The stress in those connections was 415,000 pounds tension per truss in the top, and 415,000 pounds compression in the bottom connection, to which were added 68,000 pounds tension and compression due to wind pressure assumed at thirty pounds per square foot. The top connection was made of 2–13″ [bolted together with tie-plates and connected to the pins at U_1 and U_{1a} outside of the permanent top chords, which are made up of 2–15″ [s latticed. The pins at these points were made several inches longer than needed for the permanent work for this purpose, and the long ends afterward neatly covered by especially deep Lomas nuts. The 13″ [s were supported over the piers by 2-12 x 12 braced timber bents, which rendered them strong enough to act as a runway for the traveler. They were always the last pieces assembled on the pin at U_1, each channel being slipped over the pin separately, and then connected to each other by bolting the tie-plates to their flanges—making a very simple arrangement for attaching and removing the temporary connection.

The lower temporary connection—*i. e.*, the temporary continuation of the lower chords—was made as follows: The adjacent ends of the pedestals of the two spans were planed square, as shown, and cast-iron wedges were placed between them, and securely bolted in place. The castings were made wedge shaped, to facilitate their removal after the completion of a span in case they became jambed.

It will be noted that the roller end of the cantalevered span is placed against the fixed end of the anchor span. This was specified in the printed instructions to the erectors; for, if reversed, the entire thrust of the cantalever span would have to come on the anchor bolts of the fixed shoe before any compression could take place in the bottom chord of the anchor span, and the bolts, in all probability, would have sheared off.

The apparatus for lifting and lowering the far end of the cantalevered span is shown on plate 3. Two pilot nuts (such as were used



ARA RIVER BRIDGE. GENERAL E

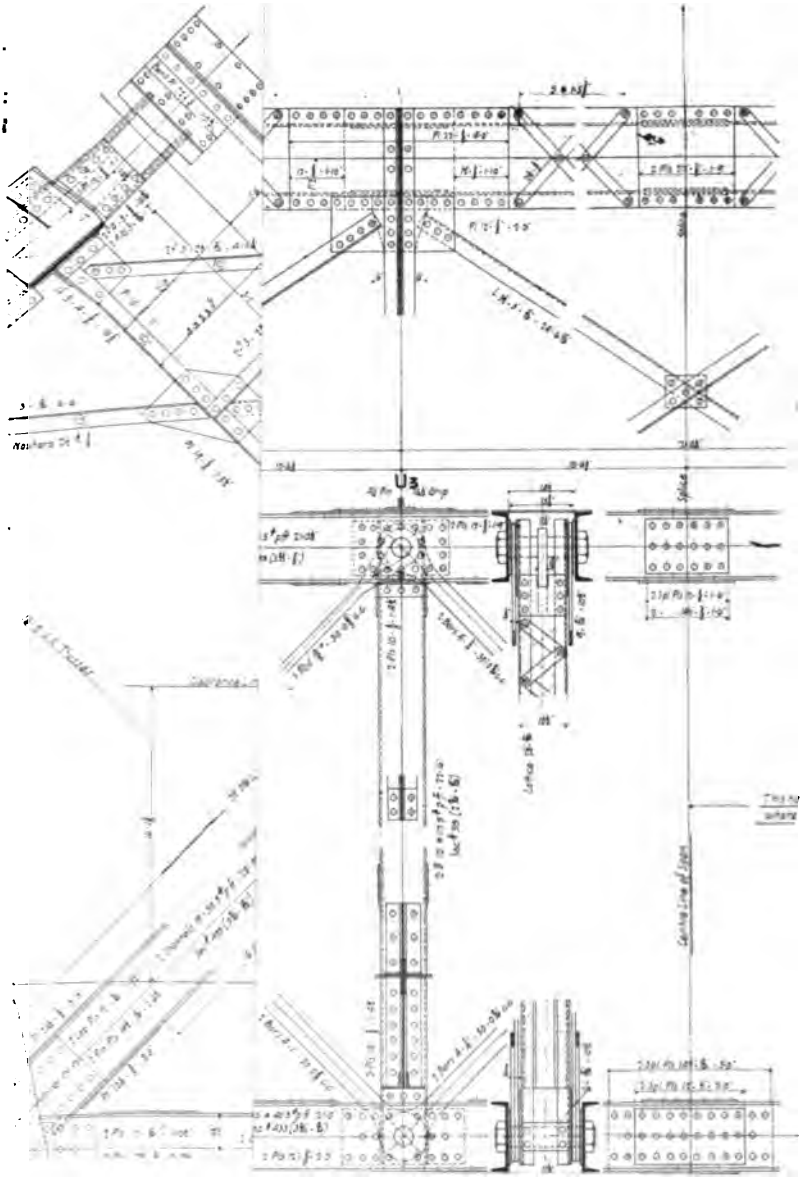
in driving the pins) were screwed to the ends of the pin at Lo on each truss to protect the thread, and two loop rods were slipped over the ends of the pin and attached at their upper ends to a cross-beam, composed of two [s that extended out each side of the shoe. A twenty-five ton jack was then placed under each projecting end of the cross-beam to furnish the power for lifting. The total calculated load was 60,000 pounds per truss. The end of the span was lifted high enough to remove all stress in the temporary tie between the two spans, which was then easily removed, and the span lowered in place on the pier.

Traveler in Position.—Plate 4 shows the traveler in position when the erection of the span was just beginning to reach beyond the pier. It also shows how the different pieces assembling on one pin were held until the pin was driven. The design of the bridge was altered considerably from the standard American design at this point to reduce the number of separate pieces to be held and their lengths, as will be shown later.

The traveler was made almost entirely of steel and was, of course, made as light as possible. The booms were about 45 feet long and composed of 2–12″ [s latticed; the posts were 8″ [s latticed, the struts 6″ [, and the diagonal bracing 1″ square rods. The traveler was carried on cast-iron wheels running on rails, which rested on short timber ties bolted to the top chords of the bridge. The crabs, operated by a few men, and shown in position on the traveler, furnished the power used for hoisting. The maximum load lifted by each boom was between 8000 and 9000 pounds.

General Drawing of Bridge.—Plate 5 is a general plan showing the details of the finished structure. It can be noted at a glance by those familiar with American standard designs that there are many changes in details. At U_1 the hanger is riveted to a large plate attached to a short piece of the top chord. The top chord extends beyond the pin, and the end post is cut off below the top chord, is reversed, and passes inside. This arrangement was made necessary by the cantalever erection, to provide the material needed behind the pin in the top chord on account of the heavy tensile stress. Ordinarily, the hanger would have been assembled on the pin with the other members, and the top chord and end post would both have terminated at the pin with short lap plates holding them in position, and the first

TIMBER TRAVELER FOR FIRST ANCHOR OR SHORE SPAN.


U3

top-chord section would have extended nearly to U_2. The bottom chords are made up of 15″ [s, latticed, in place of eye-bars, the splices of the top chords are much heavier than usual, and the shoes have square ends planed to abut against the cast blocks; the counters are comparatively heavy, and extend into the last panel of diagonals, which is also not customary in designs erected on false work. I would add, however, that most designs at the present day would be much improved if the counters were made excessive, to provide for impact and for future increase in loading.

There is nothing unusual about the other details, except the position of the splices in the bottom chords, which are placed, in each instance, on the side of the post away from the anchor span, for obvious reasons.

The floor-beams are riveted into the posts, and extend below the pins, and the stringers are riveted into the floor-beams. The portals, sway frames, and laterals are made up of angles with riveted connections. The only pin connections are in the trusses connecting the end posts and the web system to the chords. The bottom chords are continuous, and are spliced at points a proper distance from the pins.

The weight of the bridge is as follows:

Permanent superstructure,	1,258,300	pounds.
Temporary steel work and traveler,	121,000	"
Cast-iron pin-caps,	129,600	"
Duplicates and extras,	4,000	"
Total,	1,512,900	"

Before taking up the photographic views and other matters pertaining to the field work, I will give a short summary of the actual time required to complete the shop work from the date of the first inquiry until the final shipment from Pencoyd.

On January 7th of this year the first inquiry was received, no mention, however, was made of cantalever erection.

On January 13th cantalever erection specified.

On January 16th loading received.

On January 20th quotation sent to England based on this loading and cantalever erection.

On January 24th order received for bridge; also specifications.

SETTING CAST-IRON PIER-CAPS.

On January 26th—*i. e.*, two days later—change of span length was ordered.

On January 27th stress sheet finished.

On January 31st shop drawings started, just one week from date of order, two or three days of which were wasted on account of wrong data. The shop drawings were finished and all material ordered in ten days.

On February 6th work started in templet and bridge shops.

On March 7th, just a month later, the entire structure was shipped from Pencoyd, although seven days were lost on account of the blizzard, when the shop was closed. The entire time from receipt of final data to date of shipment was forty days—*i. e.*, two days within the contract time. Excluding the seven days lost on account of the blizzard, and four Sundays, leaves twenty-nine actual working days in which the design was conceived, the details worked out, and the structure built ready for erection, including the greater part of the erection material and the cast-iron caps which were not included in the original contract.

On April 26th an order was received to replace one chord section, 25 feet long, weighing 3200 pounds, which had been lost overboard during transshipment in England. Eighteen hours after receipt of order the chord section was shipped from Pencoyd.

While the designing and manufacturing of this bridge may be considered very rapid work, it was by no means so difficult a feat as some of our so-called cousins across the Atlantic seem to think.

The capacity of the Pencoyd bridge shop ranges from 5000 to 6000 net tons per month. On the basis of 5000 tons per month, the 750 tons comprising this entire contract represent only about four days' work for the entire shop.

A few years ago this shop completed and shipped for the Pennsylvania Railroad a 73′6″ plate girder bridge, weighing 74,000 pounds, in five days from date of contract—this included the making of drawings, rolling material, etc.

One span, single track, through pin bridge, 159′6″ long, was built and shipped for the S. L. Lim. Mt. and Southern Railroad in twenty days from date of contract.

A sugar factory weighing 6,731,000 pounds was shipped in one hundred and sixty-three days; the steel work for The Land Title and

General View of Structure during Erection of Third Span.

Trust Company's building in Philadelphia, weighing 4,370,000 pounds, was shipped in eighty-one days, and the steel work for the National Export Exposition building, weighing 2,210,000 pounds, in thirty days from date of order. Other instances might be cited showing rapid construction under ordinary circumstances, but these will be sufficient to show that the Pencoyd Iron Works did not need to have the Atbara bridge "*in stock*," as so many British papers asserted. Barely two or three weeks ago the London correspondent of one of our daily papers again brought up this remarkable assertion and stated that "it had never been denied." It is not necessary to deny an impossibility, as the entire structure was necessarily a new and unusual design on account of the method of erection so foreign to our American practice.

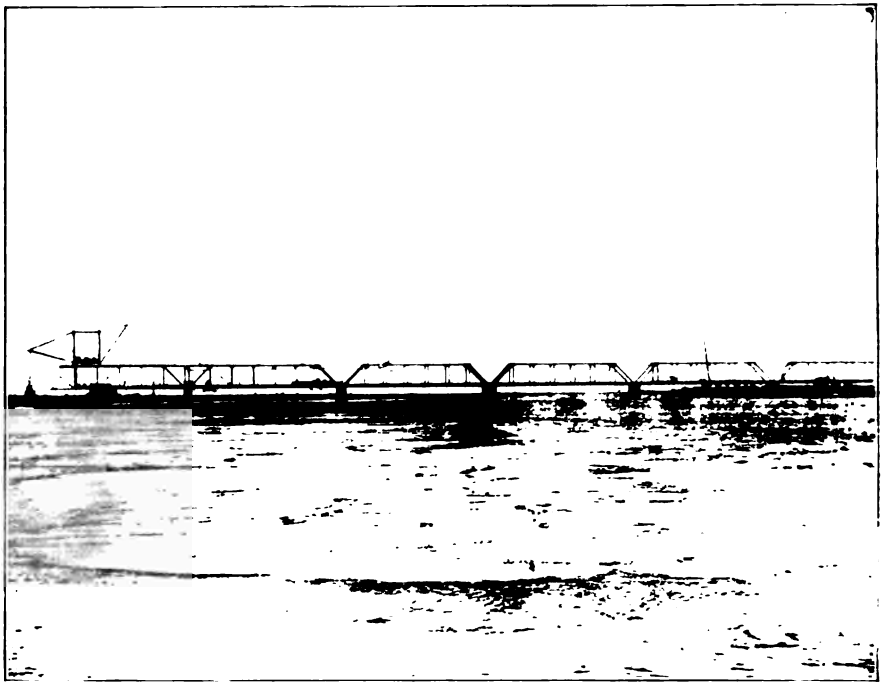
In this connection it might be stated that very few European technical papers have adversely criticized this design. "The Engineer," in one part of its article on this bridge, objected to the pin connection (the well-known British objection); and further on in the same article asked "why a pin-bridge was not suggested in the first instance to British bidders" as the best method of solving the problem.

"Stahl und Eisen," a German technical paper, published a translation of the description of the bridge as given by "Engineering," in which there were several errors. In giving the list of 62 specimen tests on the material, which ranges from 26.77 gross tons to 30.99 gross tons per square inch ultimate strength, a single typographical error changing 27.3 tons to 37.3 caused a comment on the excessive variation in the material used and a condemnation of American material in general. Another solitary error changing 28 per cent. elongation to 38 per cent. was also duly commented on, although the actual maximum was $33\frac{1}{2}$ per cent. These are the only criticisms so far noted.

A partial explanation of the difference between the time the British manufacturers specified in their bids for this comparatively small contract and that specified by the Pencoyd Iron Works and other American bidders lies in the standardizing of structural shapes and in the improved machinery in use in this country. Another explanation lies in the fact that an American bridge designer studies all designs with a view to duplication of parts to reduce templet work and tries to make the shop work as uniform as possible and in accord-

ance with an established standard. He also confines himself to standard shapes, and can, therefore, rely on receiving his material at once.

A British designer prides himself on his originality and attempts to stamp his individuality on his work; consequently, there is no uniformity in shop work. He also uses special shapes, for the same reason, so that new rolls usually have to be made for nearly every



General View of Structure during Erection of Last Span.

contract, entailing considerable loss of time with no compensation in the form of improved work. This applies equally as well to locomotives and other engineering products. The conservative policy of British manufacturers as regards machinery is well known, while American manufacturers are continually discarding the old methods and machinery for the more modern.

The following list of reasons for the superiority of American manu-

factures was taken from a British paper and is given for what it may be worth:

Low cost of raw material.
Standardizing of designs.
Elimination of the human factor.
More up-to-date machinery.
Lower freights.
Willingness to enlarge business.
Younger managers.
Better technical colleges.
The trades unions in England.
American studies of foreign requirements, and their devotion to business.

This is a somewhat formidable list.

We will now revert to the Atbara contract, which, as far as the Pencoyd Iron Works is concerned, was entirely fulfilled when the last consignment of material was placed on board ship in New York, excepting the responsibility for the proper erection as already noted. The erection crew of eight men left New York on April 22d, and from that time until their return in October were in the employ of the British government.

The bridge was shipped to Alexandria, Egypt, by way of Liverpool, requiring one transshipment at the latter place, and reached there early in May. In Alexandria it was transferred to the Egyptian Railroad, and reached the bridge site early in June, requiring three transshipments—one from broad to narrow gage at Luxor, from railway to steamer at Assuan, and vice versâ at Wady Halfa.

Although the material was considerably bent by the many transshipments, no permanent injury to it had resulted therefrom, and it was all readily repaired at the bridge site.

The entire erection crew arrived at the Atbara on June 16th. A little over two months later—on August 19th—the bridge was completely finished—*i. e.*, less than seven months from the date of the placing of the contract. This included the erection and removal of the anchor span, and actually represented the erection of eight spans and the removal of one. This would be equivalent to erecting say nine spans in sixty-three days, or an average of one span in seven days. The shortest time on any one span was four days.

A Contrast of Fifty-five Centuries. 3600 B. C.—A. D., 1800.

The entire erection was carried out precisely as planned, without the loss of life either from accident or sickness. The ordinary labor employed was composed of Sudanese and Egyptian convicts and soldiers—about two hundred men in all. An interpreter was needed to translate the orders of our foremen and men.

During the erection of the bridge two foreigners—a French engineer and an American from Columbia College—died after a few days' illness due to the climate. The erectors, although working hard, retained their health, but suffered considerably from the heat and from the depression caused by the sudden death of these men. They were also somewhat worried by the dire prediction of their Cairo landlord who, when they left Cairo, stated that usually only four or five men out of every eight ever returned from that awful climate. In this instance, however, the eight men all returned and arrived in New York October 4th, and at Pencoyd a few days later, where they received the welcome they deserved.

How well the work was done can best be expressed by quoting a part of General Kitchener's address at the formal opening of the bridge: "The opening of this bridge to-day is due to their (*i. e.*, American) energy and ability, and the power they possess in so marked a degree of turning out work of this magnitude in less time than can be done by any one else. I congratulate the American foremen and workmen on the excellent success which has crowned their efforts in the erection of this bridge in the heart of Africa, far from their homes, during the hottest months of the year, and depending solely upon the labor of men speaking a foreign tongue. They have shown by this work the real grit they are made of."

Map.—Before closing, I wish to point out the possibilities of the future for American manufacturers in Africa. This map shows the projected line of railway from "the Cape to Cairo." On the north this line is now completed to Khartoum, on the south to Buluwayo, and from Buluwayo to Rhodesia it is under construction. The entire length of the line is 6600 miles, of which about 3000 miles are completed; six lines of railway from the east coast to this line are now under consideration, of which four are partially constructed.

When we consider that the distance from Boston to San Francisco is about 4000 miles, we can realize the immensity of the Cape to

Cairo undertaking. That it will ultimately be finished is, I think, reasonably assured, as we are soon to see the completion of a similar undertaking—namely, the Siberian railway, whose total length will be about 8,000 miles. The eastern end of the latter railway is being

ROUTE AND CONNECTIONS OF PROPOSED "CAPE TO CAIRO" RAILROAD.

built almost entirely of American materials—even the shovels used by the laborers were made in this country.

The Atbara bridge should only be the beginning of American railway building in Africa—for what has been accomplished in Asia can also be accomplished in Africa.

DISCUSSION.

THE CHAIRMAN (W. C. L. Eglin).—The Club is indebted to Mr. Khuen for the very interesting and able manner in which he has described the work in designing and erecting this bridge. The daily press has frequently called the attention of engineers in general to the work that has been done in Africa by Philadelphia engineers, and all of us, I believe, have been anxious to hear more of the details in connection with this work, which has reached a point of international interest. Philadelphians, and Philadelphia engineers, have a special reason to be proud that the contract was secured by a Philadelphia firm, in competition with the whole world, and that our keenest rivals were forced to admit the superiority of the work.

We are fortunate in having with us, this evening, the foreman and a number of the party that erected this bridge. I believe that what they will be able to tell us of the difficulties they met with in erecting a bridge in a country where modern engineering resources are unknown; with laborers of an inferior grade, speaking in a foreign language, will be highly interesting. I shall be glad to offer the privilege of the floor to any of these gentlemen who care to tell us of their experience.

C. J. WENNAS.—Some of our friends are making too much of this hero business. We were picked out to go over there and put up the bridge, and while we naturally did the best we could under the circumstances, I think we did no better than any of the other men could have done. There was not so great a difference except in the climatic conditions. It was very hot, the thermometer registering 120° to 130° F. in the shade at eleven o'clock in the morning. We lived principally on meat, eating lots of goat meat and gazelle (a small antelope), plenty of wild game, ducks, rabbits, etc. The water is all right, just like Philadelphia water—wants filtering. We had as high as 250 men working on the job. They were the finest specimens physically that I ever saw, also the laziest and, I might add, the lousiest. Of course, we could not talk to them, could not instruct them, except through interpreters. They could do only one thing in one day. The man who hooked a chain on a car would not shove that car. He would call on twenty or more of his friends. They can do only one thing and it was necessary to have seven or eight different squads for each kind of work. Each span was alike. There are two classes of natives down there. Sudanese and Egyptians. An Egyptian will work a little. A Sudanese will not. They use the latter for guards and they carry rifles. Yes, we taught them to rivet. I don't know how often they pray, about five hours a day on an average. They start to pray, and it makes no difference whether they have a hot rivet in a hole or not. They are great prayers. We had several of them lashed. They have a word in Arabic which means "shut up." They made a habit of using it right along until we finally found out what it meant. We gave one of them thirty lashes. After that we did not hear that word any more. The English officers gave us the best assistance they could, all that we could expect. Of course, you can understand the feeling: suppose a party of Germans came over here to put up

some American bridge work. I do not know that we would fall in love with them right away. That was the way it went there, but they treated us all right under the circumstances. We lived in mud houses which had been built before we arrived. They dig a little hole, put water in it and build a house out of it, and then put on a roof of palm leaves. It is a good house for that climate, as it rains very seldom. The Nile is much like the Missouri river. The Nile water we drank was filtered. We did use some of the Atbara water. We did not work between eleven o'clock in the morning and three in the afternoon. We went to work at 5.30 A. M. and worked until eight; from 8.30 to 11, then from 3 to 6, or later, depending on what we were doing. It was impossible to work between 11 and 3. The highest temperature was about 130° F., in the shade.

WILLIAM R. WEBSTER.—I wish to ask if the method of erection is not new?

MR. KHUEN.—I have never heard of a similar bridge.

PAUL L. WOLFEL.—I don't know whether it is new. We simply did what common sense told us. The whole thing was carried out on very natural lines. One thing I might mention in connection with this work and the reason the bridge was turned out so quickly, is the knowledge of what a shop can do, what the shop wants, and what the mill wants and can do, and by giving special attention to these points we are able to get a structure through quickly. I think the close connection of the engineer that makes the plans with the shop is just the reason of our success. Get up your plans for a structure on simple lines, see what the mill wants and what the shop wants, and then you can do the work quickly.

EDGAR MARBURG.—I wish to state, simply as a matter of record, and not to detract in any way from the merit of the present achievement, that a somewhat similar expedient was resorted to in the erection of the Columbia river bridge, between Oregon and Washington. That bridge was built by the Edgemoor Bridge Company some five years ago. The structure consists essentially of a simple, main through span, flanked on one side by an approach deck span. In the erection of the former on the cantalever principle, one-half of the latter, in an inverted position, was used temporarily as an anchor arm at each end. The position was inverted because the chord stresses during erection were obviously of an opposite character to those normally existing in the finished structure.

MR. L. WOLFEL.—I might mention that when we took this contract we never had the least idea that there would be so big a fuss made over it. We never said much about it. We made our plans. Of course, we could not help but think what a bad effect it might have if we were not successful. I had the fullest confidence in our plans, but the least oversight might have caused a very serious difficulty, and then, of course, there would have been rejoicing on the other side.

C. M. MILLS.—In the invitation to bid, to what extent were materials, quality or character of materials, and features of design prescribed? Did you simply bid on a certain number of spans, to carry a certain load? To what extent were particulars defined in the original invitation for proposals?

MR. KHUEN.—The British government asked for bids on seven 150 feet through spans, specifying loads, unit strains, and material; also erection without

false work. They threw the entire responsibility for the erection on the company, although the final contract did not include the erection—simply included all the materials required to complete the bridge. The workmanship was in accordance with the American standard practice, subject to the inspection of a firm specified by the British government. The steel was medium open-hearth ranging from 60,000 to 70,000 ultimate strength. Basic steel was used.

THE CHAIRMAN.—The questions here discussed are of great importance to engineers, especially to those who expect to' compete in foreign markets. To-day, nearly all the manufactures are overcrowded, and the engineer is very busy with the home requirements. In a few years conditions may be reversed, and to keep our shops busy we may be forced to look for business in foreign markets. It is, therefore, very important that we should remove all of the barriers that prevent American manufacturers bidding on an equal basis with the other competitors.

The work that is being done by the International Association, of testing materials, is known to some of the members of this club. The Engineers' Club of Philadelphia could be of great assistance to all engineers by lending its aid to standardizing specifications and introducing such clauses as would admit of American methods and American materials in the engineering works of the world. It is to be hoped that the good work of Pencoyd is but the starting-point, and will be followed by engineers in other lines.

Mr. Earle can probably give us some information about the bridge in Burmah which is being built by an American company.

THOMAS EARLE.—The specifications are probably not more severe than those in this country covering the best work. There is, however, a tendency to interpret them more rigidly, particularly in matters which we consider of small importance. Either acid or basic open-hearth steel may be used.

The work of erection will be done by a small force of Americans—about fifteen—and a large force of natives. The favorable season for doing this work is from November to March. The viaduct is over a dry gorge, and is about 2300 feet long and 320 feet high at the highest point. It is made up of plate and lattice-girder spans; the plate-girder spans forming the towers. The erection has just begun. Many of the inquiries received for work to be done under the supervision of English engineers specify that only acid open-hearth steel shall be used.

ABSTRACT OF MINUTES OF THE CLUB.

BUSINESS MEETING, November 4, 1899.—The first Vice-President in the chair. Seventy-one members and eleven visitors present.

The tellers reported the election of Messrs. A. B. Eddowes, Richard Khuen, Jr., and H. H. Patterson to active membership, and L. C. Dilks to junior membership.

William H. Burr, of New York city, presented a communication on "Long-span Bridges." The subject was discussed by Messrs. Marburg, Christie, and Deans.

REGULAR MEETING, November 18, 1899.—The first Vice-President in the chair. Seventy-eight members and twenty-one visitors present.

A memorial of the late Walter Dubree Heston was presented and ordered to be entered upon the minutes.

Richard Khuen, Jr., read a paper upon "The Athara River Bridge." The subject was discussed by Messrs. Wennas, Christie, Webster, Wolfel, Marburg, Earle.

BUSINESS MEETING, December 2, 1899.—The second Vice-President in the chair. Forty-nine members and six visitors present.

The Secretary announced the death of Richard B. Osborne, which occurred on November 28, 1899.

Nominations for officers for 1900 were presented as follows:

For President:	*Proposed by:*	*Seconded by:*
EDGAR MARBURG.	James Christie.	Wm. C. L. Eglin.
For Vice-President:		
STRICKLAND L. KNEASS.	T. Carpenter Smith.	M. R. Muckle, Jr.
L. Y. SCHERMERHORN.	Francis Schumann.	Carl Hering.
For Secretary:		
L. F. RONDINELLA.	Henry Leffmann.	Minford Levis.
For Treasurer:		
GEO. T. GWILLIAM.	Minford Levis.	Edward K. Landis.
For Directors:		
JAMES CHRISTIE.	Henry Leffmann.	Wm. R. Webster.
W. P. DALLETT.	John F. Rowland, Jr.	James Christie.
ALLEN J. FULLER.	J. C. Trautwine, Jr.	Geo. S. Webster.
CHAS. HEWITT.	Francis Head.	H. B. Nichols.
H. V. B. OSBOURN.	C. H. Ott.	John F. Rowland, Jr.
CHAS. PIEZ.	Henry Howson.	Geo. T. Gwilliam.
WM. L. SIMPSON.	John E. Codman.	J. Chester Wilson.
E. F. SMITH.	W. B. Riegner.	Edwin F. Dawson.

The chair appointed Messrs. Eglin, Trautwine, Hering, Dow, and Furber as a special Committee on Nominations, in accordance with the requirements of the By-Laws.

The tellers reported the election of Messrs. W. Devereux, W. Fowden, F. Furness, and J. W. Henszey to active membership, and H. M. Ingham to junior membership.

Mr. Chas. Hewitt presented a contribution on "The Motorman as an Element of Street Railway Economy." The subject was discussed by Messrs. Hering, Marburg, Myers, Furber, and Eddowes.

REGULAR MEETING, December 16, 1899.—The President in the chair. Seventy-six members and sixteen visitors present.

Mr. Charles J. Dougherty presented a paper on "Electrical Process of Annealing Armor Plates in the Construction of War-ships." The subject was discussed by Messrs. Eglin, Easby, Hering, Marburg, Trautwine, Schumann, and Miller.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

STATED MEETING, November 18, 1899.—Present: The Vice-Presidents, Directors Smith, Evans, Levis, and Souder, the Secretary, and the Treasurer. The first Vice-President in the chair.

The Treasurer's report showed:

Balance on hand, October 31, 1899, ... $1035.03

The resignation of Frederick B. Miles from active membership was presented and accepted.

STATED MEETING, December 16, 1899.—Present: The President, the Vice-Presidents, Directors Humphrey, Ott, Smith, Evans, Levis, and Souder, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance on hand, November 30, 1899, ... $1145.09

Resignations from active membership were presented and accepted from Messrs. C. A. Hexamer, I. A. Stearns, H. C. Slater, J. B. Rohrer, W. L. Hoyt, H. V. Loss, H. A. Schofield, H. S. Hering; and of W. J. Hamlin from associate membership.

ADDITIONS TO THE LIBRARY.

FROM THE MILITARY GOVERNOR, HAVANA, CUBA.

Remarks on the Industrial, Economic, and Social Conditions Existing in the Department of Havana, 1899. Annual Report, Dec. 22, 1898, to June 30, 1899.

FROM THE BUREAU OF WATER, PHILADELPHIA.

Report on the Extension and Improvement of the Water-supply of the City of Philadelphia, by Rudolph Hering, Joseph M. Wilson, and S. M. Gray, Commissioners.

FROM THE AMERICAN INSTITUTE OF MINING ENGINEERS.

Transactions, Vol. XXVIII.

FROM THE LIVERPOOL ENGINEERING SOCIETY, LIVERPOOL.

Transactions, Vol. XX.

FROM MASTER CAR-BUILDERS' ASSOCIATION.

Proceedings, 1899.

FROM BUREAU OF STEAM ENGINEERING.

Annual Report, 1899.

FROM MONTANA SOCIETY OF ENGINEERS.

Proceedings of the Twelfth Annual Meeting, January, 1899.

FROM THE STATE BOARD OF HEALTH OF MASSACHUSETTS.

Report, 1898.

FROM MR. RICHARD DEVELIN.

The Geology of Wisconsin Water-supplies — Daniel Mead. Report on an Additional Water-supply for the City of Rockford, Ill., Nov. 25, 1891—G. T. Fanning, C. E.; D. C. Dunlap, C. E.; D. W. Mead, C. E. Notes on the Hydro-geology of Illinois in Relation to its Water-supply—D. W. Mead.

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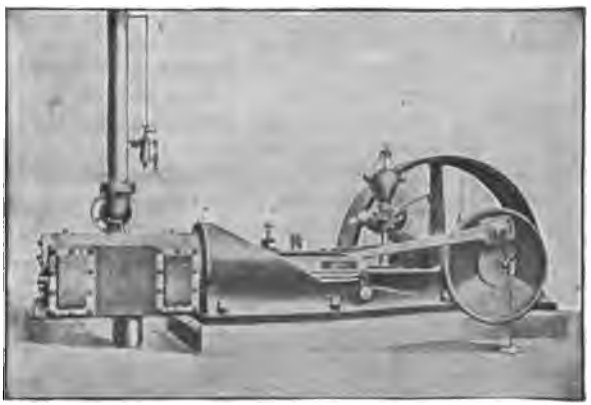

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WILLIAM CRAMP AND SONS

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Saylor's Portland Cement

HIGHEST AWARDS

Philadelphia
1876

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1893

Guaranteed the most economical for making Artificial Stone, excelling all others for fineness, strength, and constancy of volume

SAYLOR'S PORTLAND CEMENT has been continuously used by the Engineers' Department of the United States Government for the past twenty-five years

EXTRACTS FROM LETTERS ON FILE

December 19, 1876.

"I am well acquainted with 'Saylor's Portland Cement,' having tested it frequently for the manufacturers, and to some extent have used it upon the Government works under my charge. I have no hesitation in recommending its use where Portland Cement is required."

(Signed), Q. A. GILLMORE,
Brevet Major-General, U. S. A.

May 9, 1883.

"In making selection of a cement for use in the construction of Cement Jetties, to protect the eastern shore line of Sandy Hook, near the fort, I desired, all other things being equal, to encourage home productions. I decided finally to use your 'Saylor's Portland Cement.' My order covered fifteen hundred or more barrels, all of which have proven of superior quality."

(Signed), C. L. GILLESPIE,
Major of Engineers, U. S. A.

January 7, 1893.

"In reply to yours of January 5th, 1893, would say that the 'Saylor's Portland Cement' used at Old Orchard Shoal Light House, has given good satisfaction. No special tests were made, as I was well acquainted with its quality from previous use."

(Signed), D. P. HEAP,
Major of Engineers, U. S. A.

January 16, 1899.

"I have to inform you that I have recommended to the Chief of Engineers, United States Army, under date of January 14th, 1899, the acceptance of your proposal for furnishing the United States 5000 barrels of 'Saylor's Portland Cement.'"

(Signed), FREDERICK V. ABBOT,
Major, Corps of Engineers, U. S. A.

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